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ABSTRACT

These proceedings contain 271 papers in English and 15 in French, representing research and development efforts in 19 countries. On the topic of wheelchairs, 28 papers address their design, performance, evaluation, and fabrication. The field of prosthetics and orthotics is represented by 33 papers discussing devices for upper extremities, lower limbs, and evaluation and fabrication. Thirty-one papers on computers address issues relating to access, adaptations, applications, and ocular and vocal interfaces. Sections on independent living contain 34 papers relating to home and worksite modifications, ability/skill assessments, robotics, and adapted aids. Technology for the hearing handicapped is discussed in 24 papers, and 12 papers are included on technology for the visually handicapped. In the area of communication aids, 14 papers focus on the design and evaluation of various devices. The 22 papers on neural prosthetics are divided into a section on stimulation parameters and a section on functional electrical stimulation. Other sections deal with selection of technical aids, service delivery programs, technology diffusion and product development, information systems and education, biofeedback therapy, postural and seating aids, biomechanics, environmental control systems, and gait studies. (JDD)

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SECOND INTERNATIONAL CONFERENCE ON REHABILITATION ENGINEERING

JUNE / JUIN 17-22, 1984 OTTAWA, CANADA

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SECOND INTERNATIONAL CONFERENCE ON REHABILITATION ENGINEERING
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PROCEEDINGS

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Tenue parallèlement à la RESNA 7e CONFÉRENCE ANNUELLE

OTTAWA, CANADA
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MARION DEWAR

MAYOR MAIRE

June 1984.
Juin 1984

On behalf of the citizens and Council of the City of Ottawa, I am pleased to welcome you to the Second International Conference on Rehabilitation Engineering and the Seventh Annual Conference on Rehabilitation Engineering, and to the National Capital.

We were delighted to have you among us, and hope that despite your busy agenda you will have an opportunity to renew old friendships and form new ones during your stay.

I hope as well that you will have the time to explore our City, to discover the many cultural and recreational facilities available to you, and to experience first hand the warmth and hospitality of our citizens.

I extend to you my best wishes for a successful conference, and my warm welcome to our City.

Au nom de la population et du Conseil municipal d'Ottawa, je suis heureuse de vous souhaiter la bienvenue à la Deuxième conférence internationale sur la technologie de rééducation fonctionnelle, à la 7^{e} conférence sur la technologie de rééducation fonctionnelle et à la capitale nationale.

Nous sommes heureux de vous accueillir parmi nous et espérons que malgré votre programme chargé vous profiterez de l'occasion pour renouveler d'anciennes amitiés et en nouer de nouvelles durant votre séjour.

J'espère également que vous prendrez le temps de visiter notre ville, d'en découvrir les maintes installations culturelles et récréatives et que vous goûterez personnellement l'hospitalité chaleureuse de nos citoyens.

Agréez mes meilleurs voeux de succès dans vos délibérations et un chaleureux accueil à Ottawa.

Marion Dewar
Marion Dewar
Mayor/Maire

PREFACE

These are the Proceedings of the Second International Conference on Rehabilitation Engineering and we hope that they do indeed represent a truly international picture of R&D in the field of rehabilitation engineering.

Papers have been received from nineteen countries and represent a good cross section of the current interests. We are particularly pleased with the number of good papers on service delivery, assessment and evaluation; papers written and presented by "non-engineers".

1984 was predicted to be the year when technology was to have enslaved us and to have homogenized society into a grey mass. The papers in this Proceedings Volume indicate otherwise. Technology when applied, as it should be, to the needs of humanity can increase freedom, enhance life quality and give everyone the luxury of choice.

Let us hope that the papers in this Proceedings Volume continue to add to the evolution of new thoughts, new devices and new hope.

O.Z. Roy and R. Foulds,
Co-Chairmen, ICRE II

AVANT-PROPOS

Voici le compte rendu de la deuxième conférence internationale sur la technologie de rééducation fonctionnelle. Nous espérons qu'il trace en effet un portrait vraiment international de la R-D dans le domaine de la rééducation fonctionnelle.

Les mémoires que nous avons reçus de dix neuf pays refflètent assez fidèlement les intérêts courants. Nous sommes particulièrement satisfaits du nombre d'excellents mémoires portant sur la prestation et l'évaluation des services qui ont été rédigés et présentés par des personnes autres que des spécialistes en rééducation fonctionnelle.

Il a été prédit que 1984 serait l'année où la technologie aurait complètement asservi les hommes et aurait fait de la société une masse grise homogène. Les mémoires reproduits dans ce compte rendu témoignent du contraire. Lorsque la technologie est appliquée, comme elle devrait l'être, aux besoins de l'humanité, elle accroît la liberté, améliore la qualité de vie et offre à tous le luxe de choisir.

Nous espérons que les mémoires présentés dans ce compte rendu continueront de contribuer au développement de nouvelles idées, de nouveaux dispositifs et de nouveaux espoirs.

Les co-présidents, ICRE II

O.Z. Roy et R. Foulds,

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SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 1

WHEELCHAIRS I - DESIGN AND PERFORMANCE/

FAUTEUILS ROULANTS I - CONCEPTION ET PERFORMANCE

FUNCTIONAL PERFORMANCE OF FOUR MANUAL WHEELCHAIRS

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ABSTRACT - Thirteen quadriplegics using four manual wheelchairs were rated on performance of eleven functional tasks. The Quadra and Quickie scored best for regular and sports use. The E. & J. Sportsman was suited to everyday use. The Stainless scored poorly for quadriplegic use.

RÉSUMÉ - Treize quadriplégiques utilisant quatre fauteuils roulants manuels ont été évalués sur la performance de onze tâches fonctionnelles. Le Quadra et le Quickie ont remporté les meilleurs résultats pour l'usage normal et sportif. Le Sportsman E. & J. convenait à l'usage quotidien. Le Stainless pour sa part a donné de piètres résultats pour l'usage des quadriplégiques.

INTRODUCTION

Research about manual wheelchairs has been concerned with the efficiency of the chairs[1], the effort required to propel the chairs[2], and the modifications possible[3]. No objective information about the performance of different manual wheelchairs while the user is carrying out functional tasks is available. Since the wheelchair used by spinal cord injured persons highly influences their functional ability, consumers require objective information to choose the chair which allows them optimum function. The purpose of the study was to determine how four wheelchairs commonly prescribed for spinal cord injured persons perform under different situations involving functional tasks.

METHODS

The four wheelchairs chosen for the study were the E. & J. Sportsman, Quadra Fold, Quickie Rigid, and Stainless Superstar. The subjects were thirteen quadriplegic persons with C_6 and C_7 spinal cord lesions who used a manual chair as their prime means of mobility. The instrument to measure wheelchair performance consisted of an objective rating of 49 observations. The objectives of the observations were to determine how the four chairs performed during eleven functional tasks and to determine if any specific features of the chair (brakes, arm rests, rear wheels, casters, push rims, push handles, leg rests or seating position) effected the functional abilities of a person in the chair. The eleven functional tasks were bed transfers, lateral and forward weight shifts, wheeling 70 meters on a straight course, wheeling through an obstacle course, doing a wheelie, ascending and descending a 2 inch curb forward, descending a 4 inch curb backwards, propelling on grass, and ascending an incline. Each functional task was rated as successfully completed or not. Thirty-eight subtasks observations across the eleven functional tasks were rated. For example, in task #4, propelling 70 meters the length of the gym, the chair was rated on five subtasks which were: did the subject's hands slip on the rim, did fingers catch between the rim and wheel, did push handles restrict shoulder movement, did arm rests or brakes restrict stride length. The 38 subtasks were categorized according to the eight features. For example, those six subtask observations for brakes were: could the brakes be applied in the transfer position, did the brakes slip when doing bed transfers, lateral or forward weight shifts, and did the brakes restrict stride length while wheeling on a straight course or obstacle course. A standard was developed for each subtask and the functional tasks according to the importance of the task and the difficulty persons with this level of lesion would have in carrying out the task. A Pass/Fail score was determined by comparing the proportion of subjects who performed the task successfully to the standard. By adding the number of subtasks which received a pass, a Total Feature Score was derived for each feature of each chair (Table 2). A Total Functional Task Score for each chair was calculated by adding the pass scores for the functional tasks (Table 1). Although 13 subjects participated, two did not complete all tasks. If a subject was unable to perform a task in all of the chairs, these tasks were eliminated from scoring for that subject. This was a limitation of the subject's functional ability rather than the chair's performance. All subjects carried out the tasks in the same order using the four chairs. Rests were permitted between each task.

RESULTS

The results are presented in the following two tables:

TABLE 1

Functional Task Scores	E & J SPORTSMAN			STAINLESS SUPERSTAR			QUADRA F			QUICKIE			
	X/N	%	P/F	X/N	%	P/F	X/N	%	P/F	X/N	%	P/F	Standard Set
1. Bed transfers	11/13	84^6	F	9/12	75	F	11/13	84^6	F	12/13	92^3	P	90
2. Lateral weight shift	12/13	92^3	P	6/12	50	F	13/13	100	P	9/13	69^2	F	75
3. Forward weight shift	13/13	100	P	7/12	58^3	F	13/13	100	P	9/13	69^2	F	75
4. Propel length of gym	13/13	100	P	12/12	100	P	13/13	100	P	13/13	100	P	100
5. Propel obstacle course	13/13	100	P	12/12	100	P	13/13	100	P	13/13	100	P	100
6. Hold wheelie 15 sec.	2/10	20	F	5/10	50	P	5/10	50	P	4/10	40	P	25
7. Ascend 2" curb	7/10	70	F	7/10	70	F	9/10	90	P	9/10	90	P	75
8. Descend 2" curb	11/13	84^6	F	9/12	75	F	13/13	100	P	13/13	100	P	90
9. Descend 4" curb	11/13	84^6	F	8/12	66^6	F	12/13	92^3	P	12/13	92^3	P	90
10. Propel across grass	12/12	100	P	10/11	90^9	F	13/13	100	P	12/12	100	P	100
11. Propel up a hill	12/12	100	P	10/11	90^9	P	12/13	92^3	P	11/12	91^6	P	90
Total Functional Task Score	6/11			4/11			10/11			9/11			

N = Number of subjects who attempted the task
X/N = Proportion of subjects who successfully performed the task
P = % of subjects who were successful was > the standard
F = % of subjects who were successful was < the standard

TABLE 2
Total Feature Score

	E & J	Stainless	Quadra	Quickie
Brakes	3/6	3/6	6/6	3/6
Arm rests	4/6	NA	5/6	3/6
Rear wheels	4/4	4/4	4/4	4/4
Casters	2/4	2/4	2/4	3/4
Push handles	4/4	NA	4/4	NA
Leg rests	1/1	0	0	0
Push rims	5/6	2/6	5/6	1/6
Seating position	3/7	3/7	7/7	3/7

DISCUSSION

The Quadra failed in only one functional task, bed transfer. The two features receiving poor scores were the casters and the leg rests. The chair's main weakness related to functional performance was the foot rests which could be flipped up but could not be swung away. Since the Quadra is now available with removeable front rigging, the problem of foot rests interfering with transfers is eliminated.

The Quickie scored below standard on only two functional tasks, lateral and forward weight shifts. The features which related most to the poor weight shift performance were the brakes and the arm rests. The low lever brakes which slipped during weight transfer were an important functional limitation. Also the arm rest which was attached in one rear position, instead of one at the front and the rear may have provided inadequate stability for the subjects during weight shifts. The lack of push handles, resulting in an absence of a leverage point for the subjects, was also an important feature limiting function. Since the Quickie is available with toggle brakes and push handles, some of the functional limitations described would be eliminated.

The E. & J. ranked third in the Functional Task Score. Poor scores were attained on bed transfers, holding wheelies, and managing curbs. The Feature Scores showing some limitations were the brakes, arm rests, casters, push rims and seating position. Difficulties handling the arm rest lever to unlock the arm rest and difficulties replacing the arm rest decreased the subjects ability to do an independent bed transfer. Difficulties holding a wheelie and negotiating curbs relate to the rear wheel axle position and seating position of the person in the chair. There did not appear to be adequate mechanical advantage in the chair for the subjects to lift the front end of the wheelchair to ascend and descend curbs and do wheelies.

The Stainless scored poorly on bed transfers, weight shifts, curbs, and propelling on the grass. The features which contributed to poor functional performance were the brakes, push rims, leg rests and seating position. Poor performance on the bed transfers was due to the fixed foot rests. The brakes slipping during forward weight shifts, and the absence of push handles and arm rests contributed to the poor weight shift score. Although weight distribution in the chair was good enough to permit a pass score on holding wheelies, poor scores on negotiating curbs related to the subject's hands slipping on the push rims, the seating position, and low back height. These features in combination with the small casters, influenced the poor score attained on the grass. Since the Stainless does not have removeable foot rests, and does not have push handles, the problems in bed transfer and weight shift would not change. Since the Stainless is available with friction rims, the performance on curbs and grass may be improved by changing this feature. The Stainless did not perform well on functional tasks for this group of quadriplegic subjects.

SUMMARY

The Quadra and the Quickie scored well for regular and sports use for quadriplegic persons. The E. & J. Sportsman rated well for everyday use. The Stainless scored poorly for use by quadriplegic persons.

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MEASUREMENT OF WHEELCHAIR ROLLING RESISTANCE

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ABSTRACT - A "speed trap" based on a conventional lap-timer was used to measure WC drag. The efficacy of this procedure as a potential Standards test was evaluated.

RÉSUMÉ - On a utilisé un "piège à vitesse" basé sur un chronomètre classique mesurant le temps écoulé pour évaluer la résistance à l'avancement d'une chaise roulante. On a évalué l'efficacité de cette méthode comme outil éventuel de normalisation.

Rolling resistance (RR) is a major factor in wheelchair (WC) performance and should be an important consideration in the selection or prescription of a WC. While RR has been determined for a variety of tires and for a few WC's this information is not available for comparitive purposes for a wide variety of WC's, nor is it generally available to the consumer or vendor. Recognition of the importance of this information is evident from the decision of the RESNA Standards Committee to propose a test for RR for inclusion in ISO Standards for WC's. The requirements for such a test include simplicity, accuracy, reliability, objectivity and economy.

METHODS - A speed trap was constructed from three 0.55mm dia. copper wires; one to start a timer and two others at different distances from the starting wire to trigger the lap-time and stop functions of the timer, respectively. The timer used in this apparatus was a Micronta Digital LCD Model 23-115 Stop-watch (Radio Shack $29.95). This device displayed elapsed time in minutes, seconds and hundreths of seconds. It was determined that switch activation of the timer required continuous contact for 0.016 s. The switch terminals of the timer were connected to the trip-wires of the speed trap with the common lead from the timer mounted on a WC. This common lead terminated in a thin strip of spring steel which slid along the surface and made contact with the trip-wires in sequence. Three series of trails were conducted on a ramp with a slope of 1 in 12 with the second wire positioned at distances of 32.5cm, 65cm and 97.5cm, respectively. The third wire was positioned 130cm from the first wire in all tests. The WC was positioned randomly about 3cm to 5cm above the starting wire with a occupant aboard and released to accelerate through the trap. A second series of tests was also performed on a "level" tile floor using the 32.5cm and 97.5cm positions for the second wire. The ramp series were included because the ramp is a part of several other tests proposed for ISO Standards and because it provided a uniform surface which would facilitate constant acceleration. Ten trials were conducted for each condition.

Acceleration of the wheelchair was determined from the following equation:

$$a_{WC} = \frac{2(d_2 t_1 - d_1 t_2)}{t_2 t_1 (t_2 - t_1)}$$

where, d_1 = distance from 1st to 2nd wire

d_2 = distance from 1st to 3rd wire

and, t_1 and t_2 are the times corresponding with d_1 and d_2.

The a_{WC} is the acceleration due to drag (a_D) for the flat coast down test. To determine a_D for the ramp test it is necessary to subtract a_{WC} from the slope component of g:

i.e., $a_D = \frac{9.8}{12} - a_{WC}$

Drag is determined by the product of a and the combined mass of the WC and occupant.

RESULTS - A mean value was calculated for RR from the experimental data for each condition after deleting the highest and lowest observations from each set of trials. The means and standard error for each condition are shown in Figure 1. The conditions R1, R2 and R3 represent the means obtained from the ramp tests with the middle wire at 32.5, 65, and 97.5cm, respectively. The C1 and C2 condition represent the flat coast down tests, respectively.

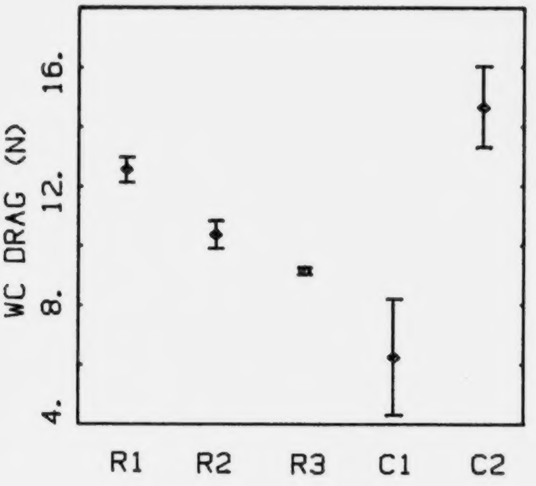

FIGURE 1

DISCUSSION - An inspection of Figure 1 suggests that the R3 test produced accurate and reliable results. The mean value of 9.12N for RR is in reasonable agreement with values obtained for similar WC's on similar surfaces by other experimental methods. The SE of 0.122N would further suggest a high degree of confidence in the measurement. However, the value of 10.35N for test R2 is also within an acceptable range of RR values, and the respective SE's for both R1 and R2 are also low enough to justify confidence in the tests. The results for tests C1 and C2 are not acceptable.

There is no reason for a_D to be different among the three ramp tests since the same area of the ramp was common to all three with only the middle wire in different positions. The potential sources of error would appear to be a function of distance and timing accuracy. Error analysis with respect to distance reveals that the WC rolled 0.3cm in the 0.016s interval from initial contact with the 1st wire to timer activation and 1.9cm and 2.2cm, respectively during the activation of the timer for times t_1 and t_2. Analysis of error due to these distance increments reveals that the value of a_D is affected by less than 2%. Since the three wires were positioned with considerably greater precision than these distances any, error in location of the wires would also be less than 2%. This would result in an overall "distance" error of less than 0.4%.

The limit of accuracy of the timer was 0.01s. This could have resulted in a maximum error of +0.009s or -0.009s in the determination of t_1 and t_2, which would result in an error of 75% in a_D. However, since the timer displays only to 0.01s any increment of time from 0.001s to 0.009 would be dropped and result in an underestimate of t_1 or t_2, as the case may be. This possible deletion of time would potentially explain much of the consistency in the data. Further error analysis reveals that the probability of error in a is 24% or greater for 56% of all observations.

It is likely the error could be reduced to acceptable levels through the use of a timer with greater resolution or one with a rounding function and by extending the distances. If a floor is used for a trap test it should be reasonably level and smooth, conducted at fairly high speed and performed in both directions.

ELECTROMYOGRAPHIC ANALYSIS OF SELECTED UPPER EXTREMITY MUSCLES DURING WHEELCHAIR PROPULSION

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ABSTRACT - Electromyographic activity was determined for eight upper extremity muscles during wheelchair propulsion at power outputs of 20w and 40w at 4 km/hr for three paraplegic and three ambulatory subjects. The EMG signals were used to determine muscle activity corresponding with generation of torque during wheelchair propulsion. There were specific patterns of activity for each of the selected muscles.

RÉSUMÉ - On a déterminé chez trois paraplégiques et trois sujets ambulatoires l'activité électromyographique de huit muscles des membres supérieurs en cours de propulsion d'un fauteuil roulant pour des puissances de sortie de 20 et 40 W à 4 km/h. Les signaux EMG ont servi à mesurer l'activité musculaire correspondant à la production d'un couple en cours de propulsion. On a établi des structures d'activité particulières pour chaque muscle étudié.

Muscle function during wheelchair propulsion is a major determinant of propulsion efficiency and ease of handling. Among factors which likely influence wheelchair performance as a result of their effect on muscle function are relative positon of the user to the handrims, the resisting force, and extent of disability of the user. The present state of knowledge of muscle function and the effects of these factors during wheelchair propulsion is almost exclusively based on anatomical deduction. The wheelchair propulsion stroke is deceptively complex and involves motion and/or forces in three dimension at the shoulder girdle and in the gleno-humeral articulation and includes both open and closed chain motion. It seems unlikely that a comprehensive analysis of the various muscle actions could be accomplished by means of observation and anatomical deduction. The defintive procedure for determining the presence of muscle activity during motion is EMG analysis. Despite the potential value of comprehensive knowledge of specific muscle actions during the wheelchair propulsion and the effects of such factors as relative position for wheelchair design and prescription, there has been only one study in which EMG analysis has been utilized (4).

The present study was conducted to determine the temporal sequences of EMG activity of selected muscles corresponding with the propulsion stroke and the development of torque and to determine differences in muscle activity at different power outputs. The responses of paraplegic wheelchair users were also compared with those of ambulatory subjects.

Methods - Six male subjects ranging in age from twenty to thirty-six years were selected on the basis of their muscular upper body physique and their informed consent. Three of the subjects were paraplegics with spinal lesions ranging from T_{8-9} to L_1. The remaining three subjects had no physical disabilities.

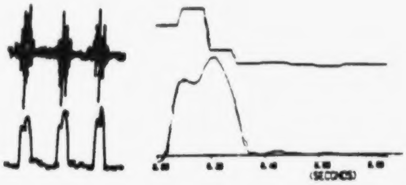
Eight right upper extremity muscles were selected for analysis on the basis of their presumed involvement in the wheelchair propulsion stroke and their accessibility via surface EMG electrodes. They included: Brachiorcedialis (BR); Biceps Brachii, long head (BB); Triceps Brachii, lateral head (TB); Pectralis Major, clavicular head (PM); Anterior Deltoid (DA); Posterior Deltoid (DP); Senatus Anterior (SA); Trapezius, upper fibers (TR).

Motor points for each of the muscles were located by means of a neuromuscular stimulator. Beckman miniature Ag/AgCl electrodes were postioned for bipolar recording of EMG signals. The signals were transmitted in the 181 to 187 MHz band utilizing differential pulse width modulation by meas of an L & M model 1006 telemetry system. The receiver passed signals in a bandwidth of 20 to 400 Hz with maximum response at 110 Hz at an input voltage of 0.8 mV. EMG signals were sampled for 5-second intervals during simulated propulsion at 1000 Hz through an A-D converter to an LSI-11 micro computer and stored on a floppy disk. Wheelchair propulsion was simulated with a motor compensated wheelchair dynamometer with independent bi-lateral inputs. Dynamometer torque and speed and handrim torque were sampled at 50 Hz sychronously with the EMG signals and also stored on disk. Because muscle monitoring was limited to three channels it was necessary to sample the muscles in series. Six trials for each subject were required to obtain recordings for eight muscles at two power outputs. Close attention was given to speed and stoke cadense to insure consistency in the stroke over the different data collection trails.

Analysis of the data was based on inspection of temporal plots of the raw EMG (REMG) patterns with respect to plots of the handrim torque. The torque and data were also folded and displayed as the average torque cycle and corresponding folded and integrated and averaged EMG cycle for the 5-second sampling interval. The Emg integration was based on summations over 100 mS intervals. Observations of muscle activity were made with respect to temporal percentage of cycle, phase (drive or recovery) of cycle, and intensity of activity (no activity, low, moderate, and peak) relative to baseline.

Results - There were considerable individual variations in muscle activity patterns. However, some distinct patterns of activity were apparent. A typical illustration of the REMG and IAEMG patterns relative to the propulsion cycle and development of handrim torque is presented in Figure 1.

Figure 1



The BR was active at the end of recovery, through the torque pulse, and just after the torque pulse. BB activity was evident during the initial phase of the torque pulse, near the end of the torque pulse, and during recovery. TB activity was evident during the latter part of the torque pulse and throughout recovery. The PM was active during the entire torque pulse. The DA exhibited distinct activity during the intial portion of the torque curve and during the last part of recovery (Figure 1). The DP exhibited activity near the latter part of the torque pulse and throughout recovery. SA activity varied considerably, but activity was noted during the initial and final portions of the torque pulse, and near the beginning and end of recovery. The TR varied considerably, but appeared distinctly active at the beginning and end of the torque pulse, and during recovery.

Total activity was greater for the 40 watt for most muscles in most subjects. No apparent patterned differences in muscle activity were observed between paraplegic subjects (Subjects 4, 5, and 6) and the normal subjects (Subjects 1, 2, and 3).

Discussion - Results from the present study were similar to those obtained by Tanuka (4) for normal subjects. A description of specific patterns of functional activity for each muscle during the stroke was facilitated by analysis of a video tape of the motion. The patterns of myoelectric activity, as well as the bimodal shape of the torque pulse, indicated that a pull-push-recovery type of stroke pattern was used by the subjects to propel the wheelchair.

The BR appeared to function as a forearm flexor during the pull phase of the driving pulse, as a possible pronator during the push phase of the torque pulse, and as an antagonist to brake at the end of the push phase. The BB probably functioned as an arm and forearm flexor and supinator during the pull phase, as an arm flexor and an antagonist (eccentric contraction) to forearm extension during the push phase, and as a forearm flexor and supinator working against gravity during recovery. The TB appeared to function as a forearm extensor during the push phase.

The PM and DA appeared to function as arm flexors during the driving phase and probably contributed to forearm extension via closed diameter effect in the "push" phase of the driving phase. Both muscules may have also functioned as stabilizers during medial rotation throughout the cycle. The DP probably functioned as a outward rotator of the arm in the push phase, and as an arm extensor in the recovery phase. The SA appeared to contribute during the "pull" phase in advancing concurrently with arm flexor the shoulder girdle, and as a stabilizer throughout the cycle. The TR functioned as a stablizer and symergist during arem flexor in the pull phase, an antagonist (eccentric) working against gravity during shoulder depression at the end of the push phase, and as a shoulder elevator during arm extension in recovery.

It was expected that total EMG activity for each muscle would be greater in the 40w condition on the basis EMG activity occurs earlier in the range of motion when resistance is greater (1,3). This was true in all but a few cases. These results were consistent with those of Tanuka (4) who observed greater EMG activity for wheelchair propulsion on an 8.33% slope than for propulsion on a level surface.

No apparent differences in EMG activity patterns were observed between the paraplegic and normal subjects. The observed stroke variations among the various subjects may have been a result of task novelty, practice, or anthropometric differences. The paraplegics as a group may have exhibited a smoother and more consistent stroke attributable to practice (2). Yet no distinctly different patterns of EMG activity between the two groups were observed.

EMG measurement technique can complicate the interpretation of EMG data. Better quantitative methods are needed to correlate EMG to stroke mechanics. It is often difficult to determine whether a EMG activity in a muscle is sufficient evidence to associate it with a specific movement. In many cases the function (agonist, synergist, etc) remains obscure.

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ANALYSIS OF WHEELCHAIR CASTER SHIMMY

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ABSTRACT - The equations for wheelchair caster wheel shimmy are presented along with experimental data. This analysis includes the theory and performance of single wheel casters and a new design for wheelchair casters using a dual tread wheel or co-rotating caster wheels.

RÉSUMÉ - Les équations décrivant le flottement des roues pivotantes d'une chaise roulante sont présentées, avec des données expérimentales. On examine la théorie et la performance des roues pivotantes simples ainsi qu'une nouvelle conception de roues pivotantes pour chaises roulantes utilisant une roue à double semelle ou des roues co-pivotantes.

INTRODUCTION - The rapid side to side swiveling motion of a caster wheel is called shimmy. This vibration is not a resonance phenomena but is a self excited motion which occurs above a characteristic critical speed of the caster wheel system depending on the dynamics of the situation.

More than 300 books and articles have been written about shimmy since 1920, of which only a small number are concerned with wheelchair casters. Kauzlarich, et. al. [1], Bruning, et. al. [2] and Brearley [3] have published caster shimmy information. In the analysis by Brearley, he made the assumption that the caster was attached to a rigid frame which is not the case for wheelchairs. In the paper by Kauzlarich the equation for the critical shimmy velocity is given in which a hydraulic damper with a fixed torsional damping constant was assumed for the analysis. However, wheelchairs use frictional damping at the caster spindle, and the design equations for frictional damping are related but differ from those for hydraulic damping.

It is the purpose of this paper to present the shimmy equations for predicting the critical speed at which wheelchair caster shimmy begins for frictionally damped casters, and to include the effect of a grooved tire, or co-rotating pair of tires. It is intended that these equations will give the design engineer sufficient information to avoid problems with caster wheel shimmy.

MODEL - In the initial caster wheel experiments by Bruning [4], he found that when the caster went into shimmy the frame also vibrated, and that for small angle shimmy there was no measurable indication that the caster wheel slipped on the floor in its lateral vibration. For the low speeds of wheelchairs with their relatively rigid caster wheel tires, a simple two degree of freedom model is adequate. The model assumes that the tread may or may not be separated by a groove or that co-rotating wheels are a part of the design. The plan view of the model is shown in Figure 1. If the groove width B=0 the model will give results for a single tread wheel. As shown in the model, when the caster wheel is deflected sideways a restoring normal force is developed between the wheel and floor, F_n. In addition, for co-rotating wheels a restoring moment is produced by the frictional forces F_T acting on both treads due to the rotation of the caster wheel as it is deflected. If the wheels were not co-rotating the latter restoring moment would not exist. In the case of a single wheel the restoring moment due to rotation when deflected is negligible for wheelchair casters. Frictional damping is assumed to take place between the spindle and caster bearing block. The wheelchair frame exerts a restoring spring force on the bearing block which can be measured directly. The apparent mass of the bearing block M_1 is determined by measuring the lateral natural frequency of the frame and bearing block system without the caster wheel and fork and applying the equations of simple spring-mass vibration. The mass moment of inertia of one wheel about a diameter, I_w, and its mass, M_w, are needed for the calculations. The usual small angle assumptions are used in the analysis.

DESIGN EQUATIONS - In designing a wheelchair caster considerations of strength and size as well as shimmy must be considered. For example, the equation for the force per unit load, P/L, needed to push a caster wheel over a threshold, where d/h is wheel diameter to threshold height, is given by

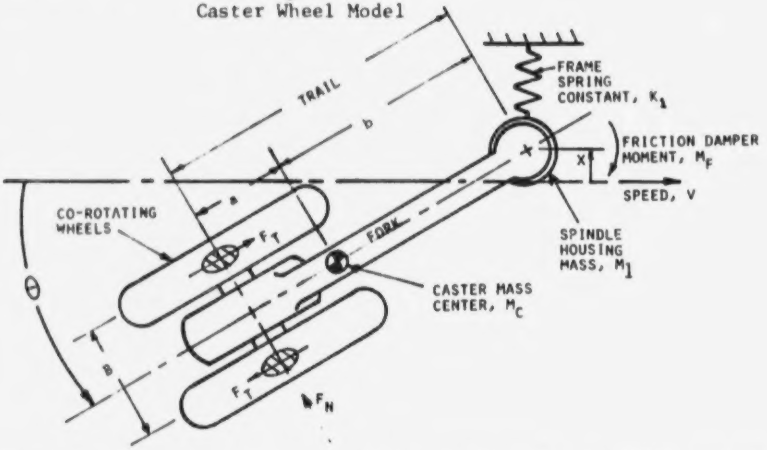
$$\frac{P}{L} = \frac{2\sqrt{\frac{d}{h} - 1}}{\frac{d}{h} - 2} \cong 2\sqrt{\frac{h}{d}} \qquad (1)$$

A few calculations using Eq. 1 will show that for a small threshold height on the order of 1/2 inch P/L increases rapidly for wheel diameters below 6 inches. Although strength and dynamic performance are necessarily a part of the design considerations, only the design for shimmy will be considered further in this paper.

The differential equation for the model shown in Figure 1 is third order, and has a solution of the form:

$$\theta = C_1 e^{\lambda t} + e^{\mu t}(C_2 \sin \omega t + C_3 \cos \omega t) \qquad (2)$$

Figure 1
Caster Wheel Model


TRAIL
b
a
FRAME SPRING CONSTANT, K_1
FRICTION DAMPER MOMENT, M_F
X
SPEED, V
SPINDLE HOUSING MASS, M_1
CASTER MASS CENTER, M_C
CO-ROTATING WHEELS
FORK
F_T
F_T
F_N
θ
B

The coefficients of Eq. (2) can be determined assuming an initial deflection of the caster wheel of θ_o giving an equation valid at the transition from stable to self excited operation of

$$\frac{\theta}{\theta_o} = \frac{\omega^2 \frac{T^2}{V^2}}{1 + \omega^2 \frac{T^2}{V^2}} e^{-\frac{V}{T} t} + \frac{1}{\sqrt{1 + \omega^2 \frac{T^2}{V^2}}} \operatorname{Cos} (\omega t - \phi) \qquad (3)$$

The first term in Eq. (3) approaches zero in less than one cycle for wheelchair casters and Eq. (3) can be simplified to

$$\frac{\theta}{\theta_o} \cong \frac{V}{\omega T} \cos (\omega t - \Phi) \qquad (4)$$

Applying the Hurwitz-Routh stability criterion to the differential equation of the model, and assuming a hydraulic damping coefficient C_D the equation governing the onset of shimmy is

$$Vc^2 - \frac{C_D T\, V_c}{I_w} - \frac{K_s\, B^2\, T}{2\, I_w} = 0 \qquad (5)$$

To reduce Eq. (5) to the case for a frictional damper with a resisting torque or moment of M_f it is necessary to use the relation of an equivalent damper, where

$$C_D = \frac{4\, M_f}{\pi\ \theta\ \omega} \qquad (6)$$

Applying Eq. 4 to 6 and substituting into Eq. 5 gives the governing equation for the onset of caster shimmy, where

$$V_c^2 = \frac{4}{\pi} \frac{M_f T^2}{\theta_o I_w} + \frac{K_s\, B^2\, T}{2\, I_w} \qquad (7)$$

In Eg. (7) I_w is the caster wheel moment of inertia about a diameter, B is the effective grooved tire tread width, T is the trail, V_c is the critical velocity for onset of shimmy, and K_s is the tire slip coefficient which was found to be on the order of 1250 newtons for wheelchair tires. Our tests show that a typical initial disturbance θ_o for a wheelchair is on the order of 1 degree, and for a caster pivot using a pair of sealed ball bearings the frictional moment $M_f \cong .02$ N-m.

EXPERIMENTAL RESULTS - Bruning [4] investigated shimmy performance of several commercial wheelchair casters including the effect of a 1/4 inch groove in an Everest & Jennings 7½ inch solid gray rubber tire wheel. His results are plotted in Figure 2 along with the theoretical curves using Eq. 7. The theory and experiment are seen to agree well.

In Figure 3 the theory and test results for an Invacare 7 3/4 inch solid polyurethane tire caster wheel with and without a ½ inch groove in the tire are shown. The plot shows good agreement between the theory and experiment.

A sample calculation using Eq. 7 at a data point on Figure 3, for curve B=9/16 inches with a trail of 2 inches, is shown below.

M_f = .02 N-m, and θ_o = .88 deg (.0154 radians).

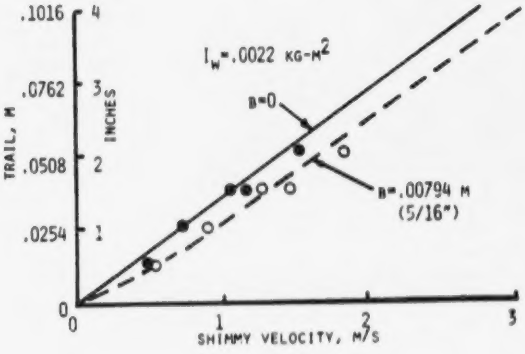


Figure 2
E & J 8" Caster Wheel Solid Gray Rubber Tire

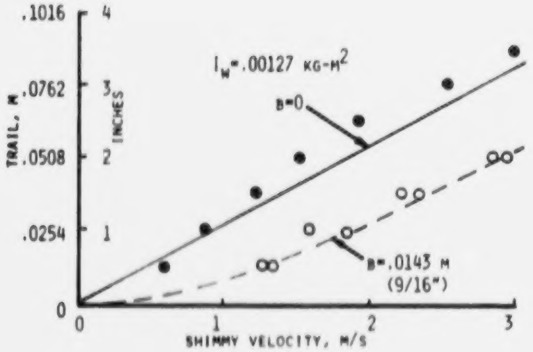


Figure 3
Invacare 8" Caster Wheel Solid Polyurethane Tire

$$V_c^2 = \frac{4\ (.02)\ (.0508)^2}{\pi(.0154)\ .00127} + \frac{1250\ (.0143)^2\ .0508}{2\ \ (.00127)}$$

$$V_c = 2.91\ \text{m/s}\ (16.86\ \text{mph}) \qquad (8)$$

DISCUSSION AND CONCLUSIONS - An evaluation of the existing theories of caster wheel shimmy was presented by Smiley [5] in 1957, including the third order system used in the analysis in this report, but not including the tire groove effect. He shows that this theory, which is one of the simplest models, applys well to caster wheels in which the tires are relatively rigid and the critical shimmy velocity occurs at low speeds.

The complete derivation of the equations and evaluation of caster wheels for shimmy is in preparation and will be published as an REC report later.

A study of the effect of the tire groove on wheelchair turning effort was carried out by Thacker [6]. He found that the ½ inch groove increased the turning effort by 10%.

In conclusion, the onset of self excited vibration of wheelchair caster wheels can be avoided by controlling the design of the caster wheel assembly. The equations show that inceasing the trail, decreasing the moment of inertia of the wheel, increasing the damping, and/or adding a groove in the tire will inhibit the onset of shimmy. All of these effects have been demonstrated experimentally and the results agree well with the theory.

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EFFECT OF SEAT POSITION ON WHEELCHAIR PROPULSION EFFICIENCY

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ABSTRACT - Wheelchair propulsion efficiency was determined for both rims and levers for combinations of 3 seat heights and 3 seat positions. Comparisons and regression analyses were conducted. Differences were found, and significant relationships were determined between efficiency and anthropometric factors for rim propulsion.

RÉSUMÉ - On a déterminé l'efficacité de la propulsion d'une chaise roulante, avec des jantes et avec des leviers, pour des combinaisons de 3 hauteurs et de 3 positions du siège. On a effectué des comparaisons et des analyses de régression. On a trouvé des différences et l'on a déterminé des relations importantes entre l'efficacité et des facteurs anthropométriques dans le cas de la propulsion avec la jante.

The ease or difficulty experienced in propelling a wheelchair (WC) will have a considerable influence on the mobility and lifestyle of many disabled individuals. The majority of WC's in current use effectively limit mobility due to their low efficiencies. This is due to several factors which are influenced by compromises to achieve general utility. The recent emergence of WC athletics has demonstrated the potential for increased performance and mobility. This has resulted in the development of a new generation of lighter, and more maneuverable WC's. One development that is apparently consistent with increased propulsion efficiencies has been the provision for adjustment of the seat to wheel orientation. While this relationship has been studied by a few investigators the results have not provided much information beyond confirming that increased performance can generally be obtained by moving the seat backward relative to the wheels and adjusting the height to provide good access to the handrims. More thorough analysis to provide quantitative information on the interrelationship among such factors as efficiency, seat height and position, and anthropometric factors such as extremity length, stem length, weight and strength would be useful in the selection and prescription of wheelchairs.

The handrim is an effective propulsion interface which provides the user with maximum feedback and control. It is also the simplest and probably most reliable form of propulsion system. Despite these significant advantages it has been demonstrated that crank and lever systems are generally more efficient (1,2,3) and in some instances offer additional advantages such as variable mechanical advantage. The latter capabilities can provide the basis for dramatic increase in performance at both ends of the WC dependent population.

This investigation was designed to determine quantitave relationships of seat position, efficiency and subject factors to provide a basis for more effective design and prescription of WC's. It was also intended as a basis for comparison of lever and handrim propulsion. The latter comparison is limited, however, to a single condition of performance for a discrete population.

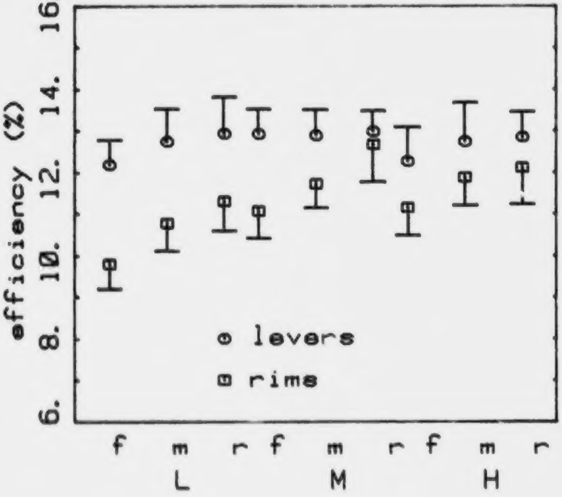
METHODS - Nine male subjects, ages 18-36, gave informed consent to participate. Eight were paraplegic (T6-L1) and the remaining was a unilateral AK amputee. Testing was conducted at the U.Va. REC. The subjects performed simulated WC propulsion activities at a nominal power setting of 20 W at 4 km/hr on a motor compensated dynamometer with independent, bilateral control. The seat was adjustable in height and along the horizontal axis.

Each subject performed nine bouts of simulated WC propulsion with handrims and also with levers for various combinations for three seat heights of 2, 4, and 6 inches above the hub axis and three horizontal positions of 0, 4, and 8 inches and 4, 8, and 12 inches, respectively for rims and levers.

Oxygen consumption and heart rate were determined for each minute of work until a steady state condition was established. Dynamometer torque and speed and rim (or lever) torque were sampled during the last minute of a bout through an A/D converter to an LSI-11 microcomputer and stored on diskettes. Anthropometric and performance factors included weight, sitting height, upper extremity segment links, grip strength and pushing strength.

A two-way ANOVA for repeated measures was used to compare efficiency with respect to seat position independently for rims and levers. A stepwise regression analysis was also conducted to determine the extent to which efficiency could be predicted from anthropometric and position factors.

Figure 1



RESULTS - The means and standard errors for efficiency for each seat position for both levers and rims are presented in figure 1. An inspection of figure 1 reveals that the efficiencies were uniformly higher for levers than for rims. it is further evident that the differences among the various seat positions are small, particularly for lever propulsion. These observations are consistent with the ANOVA results. No significant differences were found among any of the comparisons for levers; however, the comparison for rims approached significance (0.05) for both height and position but not for interaction.

A large number of significant correlations were obtained among the various factors. Of particular interest were the correlations of 0.34 and 0.29 for vertical and horizontal distances from the shoulder axis to the wheel hub, respectively, with efficiency for rim propulsion. The following prediction equations were obtained:

$$\text{R. Eff} = 0.00177444\ (\text{Push}) + 0.28082341\ (\text{ExL}) - 0.05996682\ (\text{Hz Hub}) - 13.19840738$$

$$R = 0.758, \quad P < 0.05$$

$$\text{L. Eff} = 0.86812715\ (\text{AL}) - 0.28031258\ (\text{FL}) - 0.54924065\ (\text{BID}) - 0.01142451\ (\text{Push}) + 23.45803162$$

$$R = 0.862, \quad P < 0.05$$

Where,

Push = Pushing strength

ExL = Upper extremity length
Hz-Hub = Horizontal distance from the shoulder to wheel hub
AL = Arm link
FL = Forearm link
BiD = Biacromial diameter

DISCUSSION - The relatively large variances evident from the standard errors in figure 1 are consistent with the lack of significance for the ANOVA contrasts. However, the significance of the effects of seat position and anthropometric factors on propulsion become apparant from the regression analysis. This is a functionally significant result which demonstrates quite clearly the importance of positioning a user in a WC on the basis of individual characteristics. The presence of trends to indicate a best position for WC performance or a best average WC size is analgous to having a "best" shoe size for a population.

The prediction of rim efficiency is clearly related to seat position as evidenced by the inclusion of horizontal hub-to-shoulder distance and extremity length. In contrast, lever propulsion efficiency is not sensitive to seat position. This suggests that the mechanics of lever position can be adapted over a wide range of positions without loss of efficiency. This has considerable value for wheelchair design since other factors (stability, comfort, method of folding, overall dimensions, etc.) can have higher priority in design without sacrificing WC ergonomics and efficiency. It also provides such possibilities as asymmetric construction for custom seating conditions for the severely disabled user.

Lever propulsion efficiency, while relatively independent of positional factors, can be predicted effectively from functional and dimensional factors such as strength, shoulder width and segment length. Although this predictive capability is present it is of questionable practical significance.

The relatively higher values for efficiency in the rangeof 10 to 12% in contrast to the commonly observed values of 6 to 8% for rims are probably due in part to the optimizing effects of position but monthly due to the lower mechanical advantage conditions (1:1.2) used to minimize fatigue.

With further testing which will incorporate other populations of WC users it will be possible to construct useful dimensional data tables to assist in WC prescription for a wide range of users.

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THE EFFECT OF MECHANICAL ADVANTAGE ON HANDRIM PROPULSION EFFICIENCY

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ABSTRACT - Wheelchair propulsion efficiency was determined for various combinations of speed and mechanical advantage. Although there was considerable variation among subjects it was found that efficiency was generally greater at lower mechanical advantages and also at higher power outputs.

RÉSUMÉ - On a déterminé l'efficacité de la propulsion d'une chaise roulante pour diverses combinaisons de vitesses et d'avantages mécaniques. Malgré les variations considérables parmi les sujets, on a trouvé que l'efficacité était généralement supérieure lorsque les avantages mécaniques sont moindres et aussi lorsque la vitesse obtenue est plus grande.

Wheelchair (WC) propulsion efficiency is probably most important to users at the ends of the WC dependent population. For the severely disabled it could be the determining factor for independent mobility. It is also a determining factor at the other end for WC athletes seeking maximum performance. While these classes of WC users would likely benefit most from maximizing efficiency, all WC users can enjoy improved performance through increased efficiency. One of the factors that affects efficiency is the ratio of force to velocity while performing work. WC propulsion efficiecny has been found to increase substantially when the force to velocity ratio is increased during simulated performance (1,2).

The purpose of this investigation was to compare WC performance at various combinations of speed, torque and simulated mechanical advantage (MA).

METHODS - One AK amputee and eight paraplegic (t6 - 11) males, aged 18 to 36 years, gave their informed consent to participate as subjects. They performed simulated WC propulsion at nominal speeds of 2.33, 4.67, 7.0 and 9.33 km/hr at MA's of 1.21:1, 1:1, 1:1.21 and 1:2. They also performed for simulated slopes of 1 and 2 degrees at a speed of 4.67 km/hr at each MA.

Tests were conducted at the UVA-REC. Efficiency was determined from steady-state oxygen consumption and measured power output. The WC propulsion was simulated with a motor compensated dynamometer with independent bi-lateral control. Dynamometer torque and speed and handrim torque were sampled at 50Hz for 10s intervals during the last minute of each exercise test. The data were passed through an A/D converter to an LSI-11 microcomputer and stored on a diskette for later analysis. Pushing strength, grip strength, body weight, sitting height and upper extremity link dimensions were determined for each subject.

A two-way ANOVA was performed using the classifications of speed and MA to evaluate differences in efficiency for one analysis and again using the conditions of simulated slope with MA. A step-wise multiple regression analysis was also conducted to determine the incidence and extent of factors contributing to variance in efficiency.

RESULTS - The means for each condition for the various speeds and MA's are presented in Figure 1 and those for simulated slope at the different MA's are presented in Figure 2. An inspection of these illustrations reveals that efficiency increases inversely with respect to MA. It can also be seen that efficiency reaches a peak with increasing speed (power) and then begins to decline. In Figure 1, where the power increase is a function of speed, the peak efficiency occurs at successively higher power as MA decreases. Figure 2, in which the increase in power is a function of increased torque, reveals higher efficiency at lower MA's but suggests that continued increases in power would eventually result in higher efficiencies at higher MA's. Despite the substantial differences in efficiency shown in Figure 1 the results of the ANOVA comparison for simulated speed and MA were not significant for either contrast. The ANOVA contrasts were significant, however, with respect to both MA and simulated slope ($P < 0.05$). The contrasts with respect to slope revealed that efficiencies were higher for both the 1 and 2 degree slope than for the level condition. It was further found that all MA conditions were significantly different from one another ($P < 0.05$).

Several significant relationships were determined between efficiency and the experimental variables (including MA). The following was one among several significant regression equations determined for the prediction of WC propulsion efficiency:

EFF = 116.81073872 +
0.35342957(weight) - 2.14395337(FA length) + 0.43105715(grip)
-1.23220054(MA) - 0.43171286(HR)
-37.58705153(srr. period) +
0.31486979(str. pulse time)

$R = 0.803$, $P < 0.05$

Figure 1

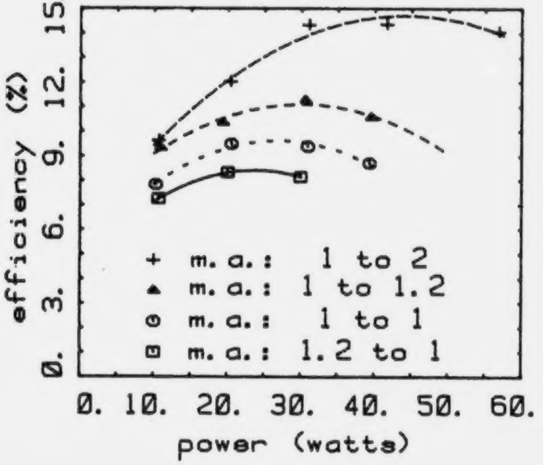
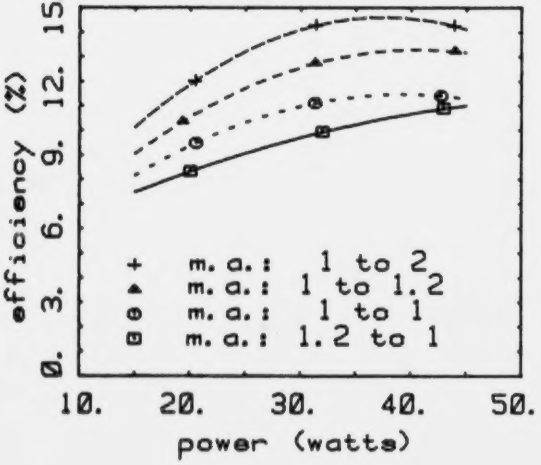


Figure 2



DISCUSSION - The influence of MA on the efficiency of WC propulsion with handrims is substantial and of considerable functional significance. The differences with respect to the experimental conditions are evident from Figures 1 and 2. The lack of significant differences among the conditions shown in Figure 1 in the ANOVA analysis was due to the considerable variance in the data. This was confirmed by the subsequent regression analysis where MA was found to be a significant predictor of efficiency.

The effect of MA appears to be the least in the range of typical WC use: i.e., 10 to 20W. However, since maximum pushing force and grip strength were also found to be significant predictors it is likely that optimal MA would be a much more important factor for weaker WC users (e.g., Quadraplegics) in this performance range.

The implications for performance are quite obvious; however, the practical utilization of these results for all-purpose WC use would require some mechanism to provide variable MA. This could more easily be accomplished with other forms of propulsion interfaces (e.g., levers, cranks). As a consequence, these results would seem to be more applicable for design or prescription of special use WC's.

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A CRASHWORTHY RESTRAINT SYSTEM FOR DISABLED PEOPLE IN WHEELCHAIRS IN MOTOR VEHICLES

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ABSTRACT - Dynamic tests have confirmed that wheelchair and occupant restraints currently in use in motor vehicles in Australia as elsewhere, are inadequate in a collision. A new wheelchair and occupant restraint system has been developed using standard seatbelt webbing and hardware to restrain both the wheelchair and the occupant, and it is now commercially available.

RÉSUMÉ - Des essais dynamiques ont confirmé que les ceintures de sécurité pour personnes en fauteuil roulant actuellement utilisées dans les véhicules à moteur en Australie et ailleurs, sont inadéquates en cas de collision. Un nouveau système d'immobilisation du fauteuil roulant et de son occupant a été mis au point à l'aide de courroies et de pièces de ceintures de sécurité ordinaires pour limiter les mouvements du fauteuil et de l'occupant, et ce système est actuellement disponible dans le commerce.

INTRODUCTION

Large numbers of disabled people achieve mobility within their community by riding in their wheelchairs in motor vehicles. It is often impractical to transfer from their wheelchair to a vehicle seat. However, no national or international Standard exists for the safe carriage of wheelchair occupants in motor vehicles. Extensive dynamic sled tests, simulating vehicle collisions at the front, side and rear, have demonstrated the inadequacy of restraint systems (1, 2).

Several new designs of restraint have been proposed, some of them requiring extensive modifications to vehicle interiors which reduce useable space and hinder general access for purposes other than wheelchair passenger transport (2). A recent article (3) describes two webbing restraints for wheelchair and occupant. In a survey of Regency Park Centre buses, we concluded that in every case the securement strength would be inadequate in the event of even a minor collision (4).

DYNAMIC TESTING

Dynamic tests of restraint systems in local use were necessary to demonstrate the problems to managements and transport officers. The technique of tying wheelchairs to side bars in the bus had not been tested in any of the US tests (1,2). We were fortunate in being able to use the test sled at Rainsfords Metal Products, manufacturers of seat belts for cars. In our tests all the restraints in local use were shown to be ineffective, even in collisions at speeds of 20 to 30 km/h. We also tested another common method of fastening wheelchairs in motor vehicles: a floor pod, stem and clamp which fastens to the wheelchair frame. It was ineffective even in a moderate collision, and in any case is only a wheelchair restraint, not a wheelchair occupant restraint.

DESIGN GUIDELINES

Our dynamic testing of existing wheelchair and occupant restraints, and the subsequent development of an improved system have led us to consider a number of aspects of the strength of securement systems:

1 Wheelchairs should not be placed in a side-facing orientation (across the vehicle) because in the event of a collision the occupant is thrown across the armrest of the wheelchair, which can damage internal organs.

2 Wheelchair securement hardware has to be strong enough to withstand in the order of 25 times the combined weight of the wheelchair and occupant for a very brief period of time (approximately 100 ms) during a collision.

3 Restraint of the disabled person must be seen as an integral part of the design. Most current restraints are designed to restrain the wheelchair alone.

4 The whole system of disabled person, wheelchair and restraint must be anchored to the vehicle. Pop rivets, wood screws and the like are inadequate for this purpose, and anchorage to a wooden floor is not recommended. Restraints should attach directly to the metal frame of the vehicle.

5 An upper torso restraint is an advantage in preventing the head from hitting vehicle structures, but there must be a method of ensuring that it can't drop below the rib-cage in a collision and damage internal organs.

6 The wheelchair vinyl seat is the support surface for the disabled person, and it must be in good repair if it is to withstand the forces applied to it during a collision.

A NEW WHEELCHAIR AND OCCUPANT RESTRAINT SYSTEM

A new concept has been developed using standard seatbelt metal fasteners and 50 mm seatbelt webbing to restrain both the wheelchair and the occupant (Figure 1). It consists of:

- webbing floor mountings at the front uprights
- webbing floor mountings at the rear
- brackets which U-bolt to the rear uprights of the wheelchair immediately below seat level: when the wheelchair is not restrained in a vehicle, the left side buckle mates with the right tongue. The brackets also secure the 2 halves of the occupant's lap belt.

TEST CONDITIONS

Because of the structural weakness of wheelchairs, it is unlikely that wheelchair occupants will ever be quite as safe in motor vehicles as able-bodied people in car seats. Dynamic test conditions for full adult restraints in cars are too difficult to attain in wheelchair occupant restraints. We propose instead the introduction of interim dynamic test conditions based on Australian Standard 1754, Child Restraints for Passenger Cars and Derivatives, except that we use a 74 kg 50th percentile adult male dummy. (These conditions are less severe than those met by the new system in 24 dynamic tests):

(i) In a forward direction, a velocity change of 50±1 km/h, during which the deceleration shall exceed 18 g for at least 20 ms. (The new system has sustained 47 km/h and 21 g.)

(ii) In a sideways direction, a velocity change of 32±1 km/h during which the deceleration shall exceed 14 g for at least 15 ms. (The new system has sustained 26 km/h and 17 g.)

(iii) In a rearward direction, a velocity change of 16±1 km/h, during which the deceleration shall exceed 8 g for at least 10 ms. (The new system has sustained 14 km/h and 10 g.)

The system successfully restrained chair and occupant in all 3 situations. A webbing chest strap around the dummy and the wheelchair uprights was used in the side and rear-facing tests.

ADVANTAGES OF NEW RESTRAINT SYSTEM

1. The system is simple, unobstrusive and suitable for buses carrying several wheelchairs as well as for small vehicles carrying one wheelchair.
2. It is applicable to the majority of existing wheelchairs without major modifications.
3. It is manufactured from automotive quality materials which are subject to automotive quality control procedures.
4. It is easy to install and it is recommended that relevant State Traffic Authorities check to ensure a safe installation.
5. It is easy to use, since all mating parts are seatbelt tongue and buckles.
6. It is commercially available from Safe-N-Sound (see address below) for only $65 (1983 price) plus installation cost.

DISADVANTAGES OF NEW RESTRAINT SYSTEM

1. Brackets must be attached to each wheelchair using the system. However, our testing has led us to believe that permanent attachments to the wheelchair will be needed to achieve a fully reliable restraint system.
2. There is no upper torso restraint and in a confined space the head may be at risk. The chair back is inadequate as anchorage for an upper torso restraint which could slip below the rib cage and damage internal organs in a collision. Use of a conventional wheelchair torso restraint if spinal support is needed in normal usage to provide support is acceptable as such a restraint is not strong enough to cause damage due to slippage in a collision.

DISCUSSION AND CONCLUSIONS

Dynamic testing of existing wheelchair and occupant restraints has revealed that they are not crashworthy even in low speed collisions. A new wheelchair and occupant restraint system has been developed and dynamically tested. It is a vast improvement on existing restraint systems in use in Australia which were designed with good housekeeping in mind, rather than crashworthiness. Eight systems have been fitted satisfactorily and we will continue to monitor feedback from users.

The new system is now commercially available. We intend to develop a Code of Practice for the safe carriage of wheelchair occupants in motor vehicles, which will provide a basis for legislation relating to the crashworthiness of wheelchair and occupant restraints in motor vehicles.

SUPPLIER

Safe-N-Sound, 229 Great North Road, Fivedock, New South Wales 2046, AUSTRALIA.

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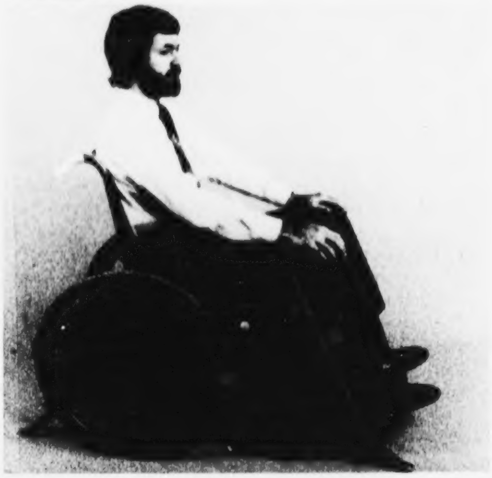

FIGURE 1 - New wheelchair and occupant restraint system.

EUROPEAN SAFETY REQUIREMENTS FOR POWER DRIVE WHEELCHAIRS

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ABSTRACT - Power drive wheelchairs are increasingly becoming a common sight on European roads and footpaths. For the protection of the wheelchair user and others, these wheelchairs must be designed and equipped so as to provide adequate safety. At present there is no internationally recognized safety standard for power drive chairs. Current developments in Western Europe, however, show that among the most important trading nations an unwritten safety codex is rapidly taking shape.

RÉSUMÉ - Il est de plus en plus courant de voir dans les rues et les voies pietonnières des pays européens des fauteuils roulants motorisés. Pour la protection de leur occupant et des autres personnes, il est impératif de les concevoir pour qu'ils soient le plus sûrs possible, et de les munir de l'appareillage nécessaire à cette fin. Pour l'instant, il n'existe pas de norme de sécurité pour les fauteuils roulants reconnue à l'échelle internationale. Toutefois, à la lumière des perfertionnements récents intervenus en Europe occidentale, il existerait un code de sécurité officieux qui tendrait à s'imposer aux nations commerçantes.

Today's modern hand driven wheelchair still conforms to the same basic folding design and construction principles developed by Mr. Jennings in Los Angeles, USA, in the early 1930's. By contrast, in the past few years Western Europe has witnessed a period of rapid development in the field of power wheelchair technology. Precluding this development, of course, has been the consequent use of the technological opportunities presented by modern solid state electronics, but also the increasingly rigid safety demands being placed on these chairs by the various national testing authorities.

An agreed standard of international safety regulations, a so-called ISO-Standard, does not yet exist. The vacuum caused by this lack of progress internationally has moved some European countries to develop their own safety standards and testing procedures. Leaders in this respect are the Scandinavian countries. Special mention must be made of the Handikappinstitut in Stockholm, Sweden, which two years ago was also awarded responsibility for testing wheelchairs awaiting licencing for the Danish and Norwegian markets. Similar test institutions, resp., authorities also exist in the Netherlands, France, the United Kingdom and West Germany.

In West Germany, the "Testing Deparment for Orthopaedic Aids and Equipments" - an affiliate body of the Technical University of Berlin - is responsible for the area of war victims reparations and provisions. It accounts for only about 5 % of total wheelchair perscriptions in Germany. Currently, the trend being followed by most wheelchair manufacturers is to submit their products to voluntary tests conducted by independent testing institutes. Once passed, these products are awarded the GS (Geprüfte Sicherheit) safety certificate. With GS-certification backing up their products, manufacturers are almost automatically afforded a strong legal position in any perspective claims suits. But the GS certificate is also valuable as a form of product advertisement. Actual testing is mainly performed through the TÜV public testing associations.

Due to the strong dependency on exports of most European countries it is of utmost importance that European wheelchair manufacturers - and not only these - remain up-to-date of the respective legal and other regulatory statutes enforced in their export markets. In practical terms this means that any economically efficient series production would have to target the goal of constructing a product that conforms to the full range of product standards and safety regulations layed down by the various national boards. For the area of power wheelchair production in Western Europe, this necessity has resulted in the development of an unwritten standard for wheelchair safety. The following remarks of the paper will be devoted to providing a somewhat more detailed description of the major categories of the above mentioned safety standard currently taking on form.

Brakes

Power driven wheelchairs require at least two independent brakes systems; a driving brake and a socalled parking brake. These brake systemsmust perform their functions independent of tyre pressure. They must also provide effective braking in the so-called deadman-circuit; this means that the wheelchair brakes will be activated automatically whenever the motors stop receiving drive commands from the control electronics. This is the case when the control stick is allowed to return to the centre or neutral position, thus effectively cutting off the supply of electrical current to the motors ore when one of the built-in safety circuits responds to a malfunction in essential wheelchair operations or components. This concept of braking is often acheived through the combination of an electromagnetic disc type brake with a regenerative brake. The regenerative brake provides gently braking action which slows down the chair, after which a time-delay circuit is activated and the electromagnetic brakes are applied to bring the chair to a gentle halt.

In order to fulfill the function of a deadman circuit the spring-activated pressure disc of the electromagnetic brake is held open by the continual flow of the electrical current.

Wheelchair Drive Controls

Infinite variation of wheelchair speed is supplied by an electronic drive control system. This unit generally consists of an impulse control generator which function according to the principle of pulse width modulation. In order to prevent a dangerous increase in speed when driving downhill, it is necessary to control drive wheel speed. Accordingly, the flow of signals to the motors must be positively controlled in order to achieve constant regulation of driving speed even when travelling on sloping terrain. This type of feedback control is generally referred to as "speed regulation". This guarantees that the wheelchair can traverse various degrees of slopes at near constant speed. The respective maximum speed must be selectable in order to accomodate the operator in learning the safe operation of his chair. Maximum speed in reverse drive must be decreased by approx. 35 %. And to accomodate the spastic wheelchair operator the drive controls must be equipped with a delayed-action acceleration circuit, which provides smooth starts even when the drive control stick is abruptly moved out of the centre position. The drive control stick should be of the four-quadrant type to permit stepless variations in travelling direction.

Emergency Switch/Safety Circuitry

The wheelchair must be equipped with an easily accessible power-off switch. In addition, a central fuse protection, preferably located directly on the battery, must provide protection against short circuits in the power supply. In case of defects affecting essential wheelchair components or a sudden drop in power, the chair must not be allowed to be driven in an unsafe operating condition. This calls for a system of automatic electronic checks and monitor circuits which are designed to detect malfunctions in the following components and/or functions:

- potential malfunctioning in the power transistor
- temperature control in the heat sinks
- malfunctioning connections between the control box and the impulse control generator
- brake functions
- battery condition

Once detected permanent malfunctions must be announced by acoustic and optical signals, and simultaneously activate the deadman-circuit, and thus bring the wheelchair to a halt. Power drive chairs should also be equipped with a dual battery control facility which also warns the operator when the batteries are running low. The electronic circuitry should also be constructed to prohibit accidental wheelchair operation during battery charging.

Motors

The belt drive system of power transmission to the drive wheels, previously common in power wheelchair construction, no longer conforms to modern safety standards. Although belt drive systems have the advantage of providing the motors and gearboxes with better protection against jolts due to drive belt elasticity, this is more than negatively outweighed by the safety hazards caused by slipping or torn belts. Of primary importance, however, is the fact that the separate construction of motors and transmission is more prone to sudden losses in braking ability than is the case with electromagnetic spring-loaded brake systems which, together with the motor, form a single, compact unit.

Wheelchair Stability

In the course of routine starts and braking the wheelchair must not be prone to tipping, even when traversing hilly terrain or other gradients. Most of today's power wheelchair models are equipped with high performance motors which are powerful enough to overcome gradients of up to 35 %. For obvious safety reasons hill-climbing ability is generally given at 20 %. It should be pointed out that this kind of driving situation is especially critical for chairs with large driving wheels in back. These chairs are steered by means of different speeds applied to the rear wheels. When driving downhill, wheelchair weight (including the operator) is shifted to the front and applied to the smaller steering wheels. This can cause the back wheels to spin, with the effect that the chair no longer will respond to steering commands.

Wheelchair Construction/Lighting

Most wheelchairs manufactured today are built according to the modular construction principle, i.e., armrests, legrests, etc. can be detached and/or are interchangeable. Seats and backs must be supplied with self-extinguishing upholstery. The physical force required to operate the drive controls should not exceed 50 N. In case the wheelchair is operated on public roads or footpaths it must also be furnished with a lighting system. Most regulations will require 2 white lamps in front, 2 red tail-lights as well as 2 rear reflectors. Regulations also require that the wheelchair be supplied with a manufacturer's identity plate, which states the manufacturer's name and the wheelchair type. Of utmost importance is that the chair is furnished with an operator's manual, containing assembly and service instructions, technical data as well as references to potential hazards of power wheelchair operation and manufacturer's liability/guarantee.

Resume

It can be expected that many of the yet unwritten safety standards for power drive wheelchairs pointed out in this short paper will find inclusion in future ISO safety standards. Due to the fact that representatives of most European testing authorities are involved in the work directed towards estabilishing an international standard, we can conclude that all of the prerequisites for above have been met.

SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 2

PROSTHETICS AND ORTHOTICS I - UPPER EXTREMITY/

PROTHÈSES ET ORTHÈSES I - MEMBRES SUPÉRIEURS

THE DEVELOPMENT OF MODULAR DYNAMIC WRIST HAND ORTHOSES TO RATIONALIZE PRESCRIPTION CRITERIA, REDUCE DELIVERY TIMES AND IMPROVE FUNCTIONAL BENEFIT

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ABSTRACT - Dynamic wrist hand orthoses are usually prescribed for patients who have suffered traumatic injury. The orthoses are frequently time-consuming to apply and this can be a serious disadvantage in patient's post-operative management. The investigations have developed a number of modular components which can be quickly assembled. Their characteristics are compared with standard commercially available devices.

RÉSUMÉ - Les orthèses dynamiques poignet-main sont habituellement prescrites pour les malades ayant subi une blessure traumatique. Souvent, l'ajustement des orthèses demande beaucoup de temps ce qui constitue un inconvénient sérieux pour le traitement post-opératoire du malade. Les travaux ont permis de mettre a point un certain nombre de pièces modulaires qui peuvent être assemblées rapidement. On compare les caractéristiques de ce nouveau système avec celles des dispositifs courants actuellement sur le marché.

Dynamic wrist hand orthoses are usually prescribed for patients who have suffered traumatic hand injuries. The prescription objectives include:

a) Hand Position. The hand should be repositioned from the deformed position to the so-called functional position.

b) Joint Motion. The range of joint motion should be preserved or increased as required.

c) Tendon Repair. The joint antagonists (extensors) should be stretched to facilitate relaxation of the protagonists (flexors). This reduces tension at the site of the tendon repair and minimises the possibility of rupture.

It is generally accepted that the timing of the application of these orthoses needs to be carefully co-ordinated with the post-operative management. It is highly desirable to achieve a satisfactory fitting at a single visit by the patient. To achieve this, we consider that two factors are important:

a) Correct Prescription. The correct prescription should be decided in a combined discussion between surgeon, orthotist and rehabilitation engineer, working as a team to assess the needs of the patient.

b) Delivery Time. The orthoses should be easily and rapidly assembled, adjusted and modified to minimise delivery times.

The hand rehabilitation services in Dundee have embarked upon a project to manufacture modular dynamic hand wrist orthoses to overcome the problems described. It was recognised that there has been very little investigation into the biomechanics of these devices and their effectiveness in promoting recovery of hand function. It was, therefore, decided to develop equipment which can be used to determine the characteristics of individual orthoses and also assess various aspects of patient hand function with and without the application of orthoses. The equipment includes:

a) Pinch and grasp transducers

b) Skin shear transducer

c) Torque transducer to measure joint stiffness

d) A polariscope to determine loci of corrective force vectors.

The equipment has been developed to produce information for rapid interpretation in busy clinical situations.

A range of modules have been fabricated and fitted to patients. The project programme currently entails a comparison of the characteristics of these modules with examples of the commonly available commercial devices. Additionally, a regular clinic has been established to assess aspects of patients hand function.

The paper will describe the development, use and assessment of the modular orthoses with the aid of the instrumentation developed.

THE PREFERRED WORKING PLANE FOR AN ACTIVE THUMB

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ABSTRACT - This study is an attempt to determine what could be the most useful mode of prehension for both orthotic and prosthetic prehension devices. In stressing the role of the thumb during prehensile activities it will be shown that despite its five degrees of freedom the thumb uses a preferred line of function both during the approach to the object and on subsequent force application.

RÉSUMÉ - Cette étude vise à définir le mode le plus utile de préhension pour des orthèses et des prothèses. En insistant sur le rôle du pouce dans la préhension, on montre que, malgré ses cinq degrés de liberté, le pouce préfère une ligne de fonction pour approcher un objet, puis y appliquer une force.

The functional versatility and the high degree of complexity of the human hand allows the prehension and efficient use of a great variety of objects. To paraphrase Aristole "The hand is the instrument of the instruments". Kapandji, has concluded his functional analysis of the hand by reporting "The hand is a perfect logical structure adapted to its different functions and for which the architectural organization reflects the principle of universal economy". (1) Such a degree of perfection may explain why the conception of a truly functional prosthetic hand still remains a challenge for the designers.

The goal of the present research is to determine if there exists for the natural hand a preferred pattern of prehension when the thumb is limited to a single active degree of freedom. In this investigation the focus of attention is on the arm-hand couple, rather than on the hand alone during both the positioning and utilization phases of prehension. The functional anatomy of prehension has been well reviewed elsewhere (1), (2), (3) and will not be further discussed here. In summary, the prehension act is a complex one since it means picking up an object with a purposeful intention. In addition, elements such as ; visual information, palpation, size and weight of the object are important. However, the "intended activity" as mentioned by Napier is crucial in determining the choice of prehensile pattern (2). Different classifications of prehension patterns have been proposed. However, it is difficult to have a classification which will account precisely for both the morphological aspect and the functional data. Consequently this investigation will be limited to the following six major prehension patterns as defined by Keller, Taylor and Zahn (4).

1) palmar prehension
2) tip prehension
3) lateral prehension
4) cylindrical
5) spherical prehension, and
6) hook prehension.

MATERIALS AND METHODS

The natural arm and hand were tested in prehensile activities. By simulating the functional behaviour of a hand prothesis an attempt was made in order to determine what could be the most favourable working angle for the thumb when limited to a single active degree of freedom. The four other fingers were also limited to a single active degree of freedom at the level of their metacarpophalangeal joint. The remaining phalanx being flexed so as to obtain a median tridigital pinch between the thumb, the index and the middle fingers. The prehension task has always been started with the forearm and hand in the functional posture, sometimes referred to as the resting posture, as defined by W.Littler (1951) (1). This is the position from which the prehension can be obtained with the minimum motion of the joints.

In this investigation the limits of the thumb's angular working range were determined whenever one of the following situations was observed:

1) During the prehension phase; a) excessive correction in the wrist posture;b) excessive pronation or supination;
2) When holding the object for use; c) incorrect orientation of the object;d) uncomfortable posture of the arm; e) insufficient stability of the object (keeping in mind the limitations of a mechanical prothesis).

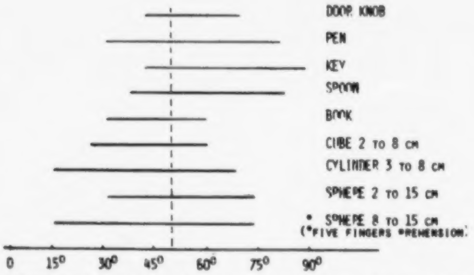
The thumb's angular working range was determined for thirty five objects commonly used in activities of daily living, together with objects listed in the "Carrol Test" (5). The measurements were taken from the orientation of the terminal phalanx of the thumb and of the middle fingers. The measurements were made on the experimenter and subsequently verified on five other subjects.

RESULTS AND DISCUSSION

In this ergonimical analysis the angular range of the working plane of the thumb is determined here with reference to the plane of motion of the middle finger. In Fig.I the thumb's angular working range is recorded for some of the objects tested. When all objects are considered it is then possible to determine the range which will allow a correct hand positioning and an efficient utilization of a maximum number of objects. The angle was found to belong to a family of working planes situated between 45 and 55 degrees. The results conform to the ones reported by Taylor. From a statistical analysis on the natural unrestricted prehension he concluded that "In palmar prehension, the thumb approaches the fingers in a plane inclined approximately 45 deg. to the palmar plane ". (7) To my knowledge this finding is not reflected in any of the actual prosthetic/orthotic hand designs.As for the natural hand, the hand prothesis uses the tridigital pinch which is considered as the most useful mode of prehension. However, in these designs the tridigital pinch has always been obtained from coplanar forces between a fixd or moving thumb and the opposing fingers. Although,traditionally used in prosthetic and orthotic designs, this prehension pattern obviously does not belong to the palmar group. In designing a hand prothesis it is believed, by the author that the exploitation of the palmar prehension and of the proposed thumb working plane, will offer the following advantages over the traditional approach:

1) facilitate hand positioning while keeping the couple arm-hand in a natural and comfortable posture
2) permit a better orientation of the object held for use
3) improve the prehension stability
4) minimize the utilization of compensatory movements, particularly during the positioning phase of the hand. For example the adduction and rotation of the shoulder joint can compensate for the lack of forearm pronation
5) increase the number of objects which can be efficiently utilized by the hand
6) can be more easily improved toward a multifunctional hand. This is mainly due to the fact that in palmar prehension, the thumb working plane is for most of the tasks, nearly similar to the ones used in the cylindrical, the spherical and hook patterns of prehension. A slight delay in the thumb motion combined with passive flexion of the terminal phlanx is sufficient to increase the number of the available patterns from one to four.

Previous investigations and experimentation on four quadriplegic subjects wearing a prehension orthosis, - designed around the above approach proved beneficial (6). Ongoing research is focused on the application and the refinement of this prehension device.



WORKING ANGLE RANGE OF THUMB VS MIDDLE FINGER FOR SOME OF THE SELECTED OBJECTS.

Figure I

CONCLUSION

It has been shown what could be the most favourable working plane for an active thumb limited to a single degree of freedom. The plane found belonged to the palmar prehension pattern.

In emphasizing the role of the thumb as the conductor of prehension and its preferred working plane, it may now be possible to outline the mechanical and biomechanical limitations upon artificial hand design.

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ACKNOWLEDGMENTS

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A NEW PAEDIATRIC WRIST ORTHOSIS

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ABSTRACT - A new paediatric wrist orthosis has been developed in order to overcome the problems encountered with conventional orthoses. The new orthosis is constructed using Tubular Orthotic components and it is designed to promote wrist extension in cases of cerebral palsy or brachial nerve damage. It has been tried on ten children.

RÉSUMÉ - Une nouvelle orthèse de poignet pédiatrique a été mise au point pour surmonter les difficultés occasionnées par les orthèses conventionnelles. La nouvelle orthèse est composée de pièces orthétiques tubulaires et est conçue de manière à faciliter l'extension du poignet dans les cas de paralysie cérébrale ou de dommage au nerf brachial; elle a été essayée sur dix enfants.

INTRODUCTION

Discussions with paediatric therapists revealed the need for a new wrist extension orthosis for children. The drawbacks of current devices center around the use of thermoplastics in the form of all encasing splints. This approach has several problems. Due to the small size of an infant or child's hand, and frequent lack of cooperation, thermoplastic splints are difficult to fabricate. Once accomplished, the child's hand is heavily weighted, effectively insulated from environmental stimulation and immmobilized from activity. The splints also need replacing frequently as the child grows.

Thus, the basic criteria for a new orthosis are: ease of fabrication and application; ease of adjustment; light weight; open volar surface for tactile input; and minimal restriction of residual grasp. Since sheet thermoplastic materials created the attendant problems, their use was rejected. Instead, a modular system of orthotics under development by the Medical Engineering Resource Unit, was brought to bear on the problem. This system, Tubular Orthotics (1), permits the fabrication of various orthoses from nylon and p.v.c. (polyvinyl chloride) tubes and meets the application, fitting and adjustment criteria.

DESIGN

The new paediatric wrist orthosis (Fig I) consists of two rings of p.v.c. tubing connnected by a rigid nylon tube. Three-point force application principle is used to push the wrist in to extension.

FIGURE I

The angle of wrist extension is set by heating the nylon tube with a heat gun, and bending it at a point 1/3 the distance from the distal end. PVC tubing is looped around the palm, cut to circumference and joined to form a ring with an end to end connector. Another ring is made for the forearm. These rings are attached to the nylon tube by "T" junctions, a dorsal pad and wrist strap are added, and the orthosis is ready to try on the child. Any required adjustments are made by changing the length of the tubes or altering the angle of the nylon tube with heat.

The final step of fabrication involves positioning the dorsal pad and securing the "T" junctions with two small screws. Fabrication takes approximately 20 minutes. The entire process is readily reversable for future adjustments, and for expansion as the child grows.

PRELIMINARY CLINICAL TRIALS

The orthosis was designed for, and fitted to, 10 children with either cerebral palsy or brachial plexus injury and who had predominantly flexed wrists. The age range was from 7 months to 13 years. Most of the children had no functional grasp and some had maceration of the palm due to an inability to extend the wrist or the fingers.

The orthosis maintained the wrist in the desired angle of extension, ranging from neutral to 45 degrees for each child. There was minimal interference with residual grasp and the palmar ring maintained slight thumb abduction at rest. This was considered desirable to inhibit spasticity. Improvement in skin condition was noted for those children with maceration, and no additional skin problems due to abrasion resulted from the orthosis.

Younger children with minimal to moderate spasticity were considered easiest to fit with the orthosis. On older children, or those with moderate to severe spasticity, the palmar arch is not maintained and the tubing tends to cut into the lateral palm. Application was also awkward for these older children.

The results of the preliminary trials were generally satisfactory. Most children were receptive to wearing the orthosis and it did maintain and promote wrist extension. The device was easily fabricated for uncooperative children, as it did not require the child's hand as a model. It was durable and easy to keep clean, and the childrens' peers were often envious of this new "high tech" device.

As orthosis interfered only minimally with residual grasp, it was preferred to any existing thermoplastic splint. The use of smaller diameter tubing is being considered to accommodate improved grasp. A definitive attachment for thumb positioning may also be developed. With the addition of a palmar arch support, use of the orthosis may be extended to children with increased spasticity. The format of the orthosis indicates that it may be useful for some adult orthotic requirements, such as a long opponens splint. The current device can serve as the base for a number of orthoses; for example, one child has been fitted with a dynamic elbow flexion assist coupled to the palmar ring.

CONCLUSION

A new wrist orthosis has been developed and successfully fitted to ten children. This orthosis is an example of a new generation of modular orthotics, where standard components are assembled quickly into a custom orthosis. The advantages are that a minimal approach to orthotics can be adopted, without the problems that accompany traditional methods. In addition, the adjustability of the orthosis is highly suitable for use in paediatrics, where small size and constantly changing needs present many problems.

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A VIDEO TRAINING AID FOR A FIVE STATE MYOELECTRIC CONTROL

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ABSTRACT - This video display training aid allows the user to develop control of his myoelectric signal in preparation for using a 5-state myoelectric control. The training aid can also be used to display the amplitude of the processed myoelectric signal.

RÉSUMÉ - Cette aide pédagogique d'affichage vidéo permet à l'utilisateur de mieux régulariser ses signaux myoélectriques en vue d'utiliser une commande myoélectrique à 5 états. L'aide peut aussi servir à afficher l'amplitude des signaux myoélectriques traités.

A small number of devices are available for training amputees in the use of myoelectric controls, such as, electric toys (1), an electric hand or other prosthetic device, or a meter-based myoelectric trainer. These training aids are for use with systems with two active states. For example, a three state controller, such as UNB 82 ABS (1), provides two active states for two movements. These could be forward and reverse in the case of a toy or open and close in the case of an electric hand. A five-state myoelectric control under development (2) offers four active states from a single myoelectric signal. Thus, a training aid was designed to utilize these states to control the movement of a cursor through a two dimensional maze. The device has an alternate mode of operation in which the amplitude of the processed myoelectric signal (MES) can be displayed in tracking studies.

Five-State Training Aid

In this mode of operation, the device operates as a stand alone training aid with a 5-state controller and video display interface built in. The system (Fig. 1) comprises a microprocessor card, a 5-state analog controller card and a video display generator card interconnected by means of an STD bus. The Intel 8085 microprocessor utilizes state information from the 5-state controller to control the direction of cursor movement through the maze. Four different mazes are stored in EPROM on the processor card; any one can be selected for display by a thumbwheel switch. Also the speed at which the cursor progresses through the maze can be selected by a second thumbwheel switch. The four mazes give a range of difficulty in terms of the sequence of state levels that must be generated by the user. Audio feedback is provided by a buzzer if the user attempts to move the cursor through a wall of the maze.

The 5-state analog controller has been previously developed (2), and has been included so that the training aid can operate in a stand alone fashion. The four active states correspond to cursor movements up, left, right and down in increasing levels of MES required to activate them. Isolation of the analog card from the system is provided through a DC/DC converter on the power supply at the input to the card and optocouplers on the four output stages.

The video display generator card makes use of a Motorola MC6847 video display generator and a Motorola MC1372 RF modulator with 6 K bytes of RAM for storage of the display information. The MC6847 is used in either high (RG6) or low (RG3) resolution mode to obtain a display of 256 x 192 pixels or 128 x 192 pixels, respectively. One of the maze patterns makes use of the high resolution mode and three patterns are used with the lower resolution mode. The appropriate mode must be selected via DIP switches on the display card. The video signal is then fed to a TV monitor for display.

Signal Amplitude Mode

In this mode, the device acts as a video display for a DEC PDP 11/34 minicomputer to provide visual feedback of the amplitude of the user's processed myoelectric signal relative to a reference or target level. A block diagram of the system is shown in Fig. 2. External analog preprocessing of the MES is done prior to sampling by the PDP 11/34 using a 12 bit A/D converter and a 3 ms sample interval. The PDP 11/34 is used to implement a signal processing algorithm to be tested. To evaluate the display device, a FORTRAN algorithm was written to perform a 100 sample moving window average. Eight data lines and 2 control lines are used to transfer information on the processed MES to the display device. The MES is represented by a centrally located vertical column on the monitor. The height of the column is proportional to the amplitude of the processed MES. The reference level is displayed as a horizontal line - one of 180 possible levels can be selected. To evaluate the device the reference levels were chosen randomly and displayed for approximately 9 seconds while the myoelectric signal was processed using a 100 sample moving window average and displayed before a new reference level was chosen.

Conclusion

A stand-alone, microprocessor-based training aid has been developed to display a two dimensional maze on a video monitor. The direction of movement of a cursor through the maze is controlled by a single myoelectric signal fed to an analog 5-state controller incorporated in the training aid. At present four mazes are used to provide varying degrees of difficulty to the user, and cursor speed can be adjusted as the user becomes more adept. Audio feedback is used to provide the user with information when a wall is "hit" by the cursor. In addition, the device can act as a video display interface for a minicomputer used in a tracking study used to evaluate myoelectric signal generation.

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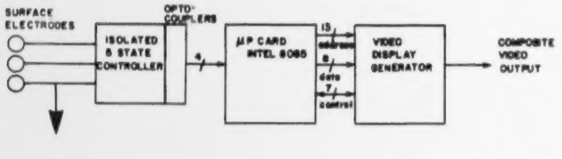
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Fig. 1 Block diagram of 5-state myoelectric training aid

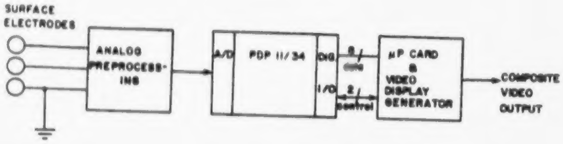
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Fig. 2 Block diagram of training aid used as a video display interface for a minicomputer

A SIMULATOR FOR EVALUATING ELBOW-PROSTHESIS DESIGNS

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ABSTRACT - The concept of a "simulator" is presented as a tool for designing prostheses. This is a high performance prosthesis worn by an amputee and interfaced to a digital controller. Desired characteristics are programmed into the controller, evaluated interactively with the amputee and subsequently modified simply by reprogramming.

RÉSUMÉ - On présente ici la notion de "simulateur" en insistant sur le fait qu'il peut devenir un outil de conception de prothèse. Le présent système est une prothèse très performante utilisée par un amputé et reliée à un contrôleur numérique. On programme les caractéristiques désirées dans le contrôleur, on les évalue lorsque l'appareil est en interaction avec l'amputé, et on les modifie grâce à une simple reprogrammation.

The work described here is part of a long term effort directed at the rehabilitation of upper-extremity movement disorders. Emphasis is placed on the development of assistive devices and the technology for their implementation instead of clinical training. Rather than deal with all of the general problem at once, the scope has been reduced to a smaller class of devices. These are single-degree-of-freedom elbow prostheses which are powered with an on-board actuator and controlled via myoelectric activity (MEA) measured from the amputee's remaining musculature.

Despite the simplifications, successful designs can be adapted readily to a broader class of assistive devices. For example, an appropriate control scheme for a single degree of freedom can simplify the control of many. Also, results based on MEA can be applied directly to the use of nerve signals when the latter becomes clinically feasible. Finally, design techniques for prosthesis joints can be applied to developing orthoses.

Why bother trying to develop myoelectrically-controlled elbow prostheses? Simply stated, such prostheses currently available to the above-elbow amputee lack some essential functional capabilities. As examples, consider the Boston Elbow (1) and the Utah Arm (2). Both offer powered elbow flexion with the angular velocity about the joint controlled via the difference between the biceps and triceps MEA. Two of the major drawbacks of this control scheme are: 1) poor coordination of the prosthesis with the remaining joints, and 2) the inability to interact with loads or constraints in the environment. Consequently the amputee's ability to perform two-joint positioning or reaching tasks is limited, as is his ability to use tools.

How can myoelectric control of the artificial elbow be improved? First of all, note that the purpose of the device is to restore limb function so that the amputee can perform tasks of daily living. Secondly, note that improvement refers to his ability to perform tasks which are either difficult or impossible with existing prostheses. Hence what is required is a means for designing assistive devices and subsequently evaluating them interactively with the amputee to see if indeed the performance has "improved". This implies an iterative technique: based on the evaluation, design changes would be implemented and the device reevaluated.

Instead of constructing new hardware after each iteration, it is desirable to simulate the prosthesis so that changes can be made simply by reprogramming. One approach might be to formulate a computer model of the complete system. Although it would be straightforward (though nontrivial) to model the prosthesis and the controller, it would be highly impractical to model the human operator and his environment. Not only does man posses complex adaptive and learning capability, but also his limb characteristics vary with fatigue. Therefore his behavior while performing a given task will change over time. In addition since the prosthesis is attached to the amputee's stump in the absence of a direct skeletal link, the dynamics of the interface must be considered. The resulting coupled, three-dimensional motion of the prosthesis and amputee will be very complicated. Moreover the environment is affected by so many factors (i.e., the task at hand) that it is difficult to characterize. Finally without the human operator directly involved, not only is an assessment of his safety hard to ascertain, but also his evaluation of the prosthesis is not available.

In this project we have taken an alternative approach: to build a computer-controlled prosthesis which allows programming of desired characteristics, and then interface the device to an amputee (3). The man is retained in his essential role while more-readily modeled components are replaced by simulation. It is not necessary to model the operator or his environment. More importantly, the experimenter's assessment of the amputee's safety and the amputee's evaluation of the design are available directly. The prosthesis simulator can be compared to a flight simulator in which the human operator, the pilot, serves his function in a seemingly real environment, an artificial cockpit, while the dynamics of the aircraft are simulated with software and hardware.

The simulator which has been constructed is a high performance elbow prosthesis. Since it is for use in the laboratory only, it is not fully self-contained; the power supply and computer controller are external to the device itself with interfacing via an umbilical cord. In designing the simulator the peak elbow torque and angular velocity were chosen to encompass the values for existing prostheses, and as closely as possible, match the values for the intact elbow (see table below). Consequently it is possible to emulate operation of the existing devices and the natural arm interactively with an amputee and compare with operation of prospective designs.

The machine (Figure 1) consists of an aerospace-technology D.C. torque motor driving the elbow via a two stage reduction (net ratio of 1:7); the first stage is a timing-belt drive and the second a low backlash gear pair. An electromechanical actuator was chosen as opposed to an electrohydraulic since it is inherently compliant (recall that the ability to give with external constraints is an important feature for prostheses). The choice of reduction components serves to minimize parasitic effects (e.g., compliance, backlash and other nonlinearities) while giving the desired peak torque. In order that the inertia and the center of gravity of the simulator match the values of the intact limb closely, the motor is situated five inches from the elbow joint. Matching of these parameters helps replicate the coupled-pendula effect of the forelimb/upper limb combination. This feature is useful whem emulating natural limb behavior, particularly arm swing during gait. Finally, the simulator has onboard position, velocity and torque transducers.

Forearm Properties (Measured from Elbow)	Value for Prosthesis	Value for Avg Adult Male
Maximum Torque (N-M)	8	60
Maximum Speed (rad/s)	12	18
Weight (N)	14	15
Center of Gravity (cm)	14	18
Moment of Inertia ($N\text{-}m\text{-}s^2$)	0.046	0.059

The immediate use for the simulator is to examine the feasibility of a prosthesis which allows the amputee to control the mechanical impedance (the torque/angle & torge/angular-velocity characteristics) about the artificial elbow similar to the way an able-bodied person can control the impedance of the intact limb. Using torque, velocity and position feedback, the computer controller can specify the mechanical impedance. In turn the amputee commands the controller with MEA. It is expected that this scheme will give the user the ability to coordinate the prosthesis with remaining joints and the ability to interact with external constraints.

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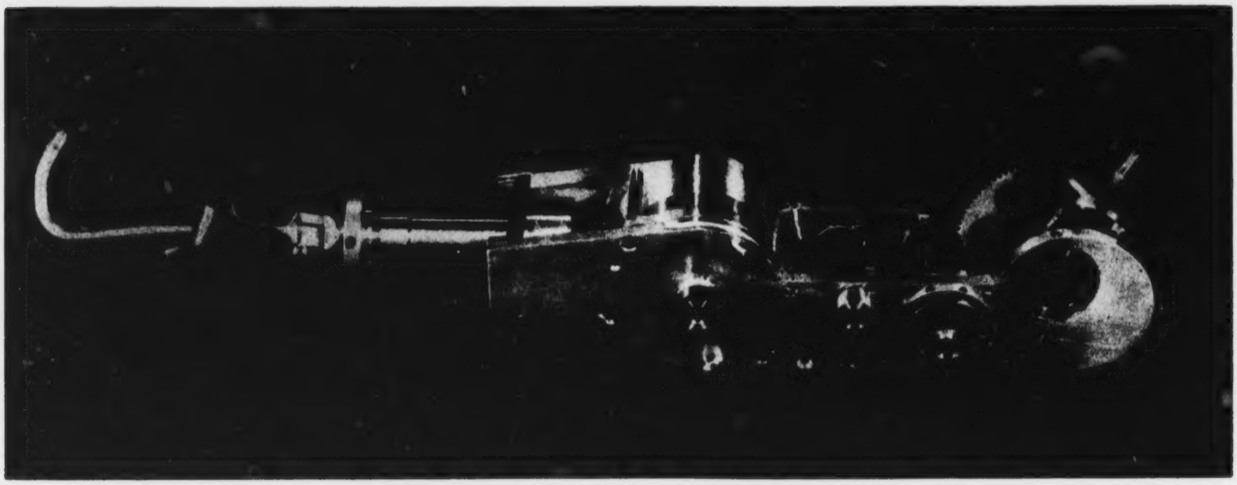

Figure 1 The Elbow Prosthesis Simulator.

A MICROPROCESSOR-BASED MYOELECTRIC CONTROLLER

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ABSTRACT - A prototype myoelectric controller using a Motorola 68701 microprocessor is described and evaluation of its performance is reported. The control algorithm is based on an analog three-state controller with added self-calibrating features.

RÉSUMÉ - Un prototype de commande myoélectrique munie d'un microprocesseur Motorola 68701 est décrit, et sa performance, évaluée. L'algorithme de commande s'inspire d'une commande analogique à trois états dotée de caractéristiques d'autoétalonnage augmentées.

Currently analog controllers are used in externally powered prosthetic devices for rehabilitation of upper extremity amputees. These controllers must have one or more parameters (such as gain or switching thresholds) adjusted to ensure proper function of the device. A prototype microprocessor-based controller has been developed based on a currently available 3-state analog myoelectric controller (UNB Model 82ABS) (1).

The UNB analog controller has a fixed signal amplification and two adjustable switching thresholds. The latter are set on the basis of signal-to-noise ratio of the myoelectric signal, and can be calculated on the basis of a mathematical model (2). The error performance of the controller is dependent on the switching thresholds being appropriate for the actual signal-to-noise ratio. Should this change, for example, due to fatigue, then the amputee may encounter difficulty in operating the prosthesis. It is also possible for the switching thresholds to be set incorrectly due to human error. It is for these reasons that a self-calibrating controller was considered desirable.

Myoelectric Controller - Hardware

A block diagram of the controller hardware is shown in Figure 1. The differential amplifier and bandpass filter are the same as for the UNB 82 ABS (1) except that a voltage offset is required for the A/D converter.

An Analog Devices AD7574 8 bit A/D converter was used to digitize the filtered myoelectric signal. The A/D converter was operated in the slow-memory interface mode with a conversion time of about 20 s. A sampling interval of 3.125ms was set by software control.

The Motorola MC68701 microprocessor has the following features on-board: 2048 bytes of EPROM, 128 bytes of RAM, three 8 bit I/O ports and one 5 bit I/O port, hardware multiplier and a 16 bit timer. In addition it is able to perform double byte manipulations. A 4.0000 MHz parallel resonance crystal was used to regulate the internal clock to give the maximum allowable internal clock frequency of 1.0000 MHz.

In addition to the inputs and control lines associated with the A/D converter, the following input and output signals are of particular interest. One bit was used to select - if desired - output of the 8 bit switching threshold values determined during autocalibration. These were used during evaluation of the system to ascertain that the controller was correctly selecting switching levels. Two bits were required during calibration to tell the operator to relax or to give a maximum comfortable contraction. Finally two bits are required for the two active states to be used to control a prosthetic device or, as in the evaluation reported here, a visual display.

Myoelectric Controller - Software

The controller has two operating modes: an autocalibration mode for selecting the required switching thresholds and a run mode for on-line control of two active states. The autocalibration mode is entered automatically upon power up. The controller waits for a ready signal via a switch on the interrupt request line after which a LED is turned on to request a strong comfortable contraction used for the "maximum" signal level. Then a second LED is turned on to request the operator to relax the controlling muscle to obtain the minimum or "noise" level. From these two values, two addresses are calculated for a look-up table containing the optimum switching thresholds calculated as in (2). The two thresholds are then tested to ensure their validity. If they are not valid, the autocalibration routine is restarted; otherwise the run mode is entered.

In the run mode, the control algorithm is operated in an endless loop as follows. An estimate of the mean absolute value (MAV) of the sampled, rectified MES is made using a 64 sample moving window average. This estimated MAV is compared against the switching thresholds and the appropriate output state is activated. The loop can be exitted only by powering down and restarting the controller.

Evaluation

The controller was evaluated in a tracking study using a UNB 3-state analog controller for comparison. A block diagram of the experiment set-up is shown in Fig. 2. Dry stainless steel surface electrodes were placed over the wrist flexor group of the right forearm. A Digital Equipment Corp PDP-11/34 minicomputer was used for experiment control, feedback of the controller output to a visual display on a TV monitor, and collection of experimental data. One of three target states ("off", "close", "open") were pseudorandomly chosen and displayed for a 2.0s interval. The operator was to match the controller output to the target state. The randomness of the target state selection was constrained so that a) no transition from "open" to "close" was allowed (since a 0.2s decision delay for "close" precludes a direct transition) and b) the same target state could be selected only three times consecutively. The target state was recorded at the start of each 2s interval and, the time and the controller state was recorded at each change in controller output state.

An experiment run consisted of a sequence of 110 target states, the first 10 of which were ignored in subsequent data analysis. A session normally comprised four runs with a rest period between runs. The microprocessor controller and the analog controller were alternated between sessions. Six sessions (3 for each controller) were performed by each of three subjects. A total of 3100 target intervals were analyzed for the analog controller and 3500 for the microprocessor controller. The data were analyzed for errors in controller state versus target state.

The errors were grouped according to the target state during which the error occurred, and they were further subdivided on the basis of the previous target state. From these results in the two active states the microprocessor controller error rate was appreciably less than that of the analog controller, although it was slightly higher in the "off" state. The difference in performance is likely attributable to the difference in the estimation of the mean absolute value using a 0.2s moving window average compared to a low-pass filter with a 50ms time constant.

Conclusion

A microprocessor-based myoelectric controller has been developed that incorporates a self-calibrating feature to set the required switching thresholds for each user. The controller-selected switching thresholds result in an error performance that is comparable to an analog myoelectric controller. Although the controller was built as a bench-top prototype, a battery-powered CMOS version could be built in a multichip design. The authors anticipate that in the near future a CMOS single chip microcomputer with all the required on-board peripherals will become available, at which time a practical prosthesis control could be built.

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Acknowledgements

The authors acknowledge the financial support of the Natural Science and Engineering Research Council through a scholarship to one of the authors (E.L.P.) and operating grant A4635.

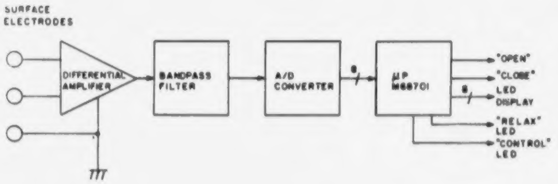

Fig. 1 Block diagram of microprocessor-based myoelectric controller

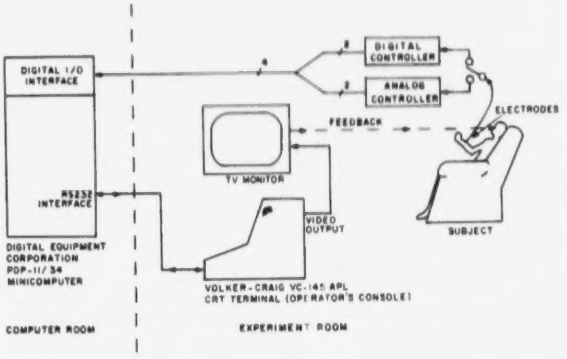

Fig. 2 Schematic representation of experiment set-up for evaluation of the prototype controller

NOISE MEASUREMENT TECHNIQUE AND CRITERIA FOR PROSTHETIC DEVICES

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ABSTRACT - This paper suggests a universal method for measuring noise emitted by motorized prosthetic devices and criteria for determining the acceptability of the noise level. These techniques could be employed by prosthesis manufacturers to standardize measurement procedures for comparisons. The method was developed while redesigning a motorized elbow, to reduce the product's noise emission.

RÉSUMÉ - Le présent rapport suggère une méthode universelle de mesure du bruit produit par les prothèses motorisées et des critères d'acceptabilité des niveaux de bruit. Les fabricants de prothèses pourraient utiliser ces critères pour normaliser des méthodes de mesure à des fins de comparaisons. Quant à la méthode, elle a été mise au point lors de la révision de la conception d'un coude motorisé, dans le but de réduire le bruit produit par l'appareil.

The noise measurement technique is a relatively complex issue requiring an understanding of the test environment, instrumentation, measurement positions, and modes of operation for the prosthetic device. Since it is not possible to anticipate all future applications of motorized prostheses, this measurement technique must provide general minimal guidelines for a recommended practice.

Some noise is desired for surrogate feedback however, many prostheses generate considerably more noise than is necessary for this purpose. If one were to meet the criterion specified in this paper, it is likely that noise levels produced by the product would still be adequate for feedback in relatively quiet environments, but would definitely be inadequate for this purpose in noisy environments such as industrial sites. It is unclear at this time whether amputees depend on this feedback mechanism for positioning a prosthesis.

This noise measurement technique is intended for use with all mechanized external prosthetic devices operating in the normal mode(s) throughout the entire range of motion, speed and load. Although not the intent of this proposal, the methods described may also be used for body powered prostheses.

There are two levels of measurements which should be considered when assessing noise emission from a prosthetic device. The first is a measurement method which would allow consumers (prosthetists, rehabilitation specialist, therapists, or the wearer) to assess the relative noise level of various competitive products. A single number rating (A-weighted sound pressure level) is recommended. The second measurement is a more complex detailed frequency analysis which would provide guidance to manufacturers during the design phase. This is essentially a criterion which would show the designer areas, in the audible frequency range, which should be reduced.

All noise measurements should be made at a distance of one meter from the geometric center of the device. Microphone height should be 1.5 meters which represents the average height of an adult male/female ear.

Directionality is a parameter which must be considered because of the infinite possibilities for source-receiver position relationships. Directivity patterns are used to describe how sound intensity varies with position around a device. Since the directional characteristics of the device being tested are not known, initial measurements should be made at three positions on a plane 1.5 meters above the floor-reflecting surface. These three positions should provide an indication of directivity. Subsequent measurements should be made at this position of maximal noise level.

The prosthesis under evaluation must be measured in a controlled environment. This test environment is intended to perform two functions:

1. Provide a relatively quiet area where tests can be performed without masking noise.
2. Provide an area free of reflective surfaces for accurate noise measurements.

In addition to the environmental and noise measurement parameters, the sound emitted by a prosthetic device will vary with the installation and operating procedure. Since this method is intended to cover a wide range of prosthetic devices, it is unrealistic to attempt to specify the exact mounting and operating requirements. Therefore, accompanying all test data should be a description of the method of mounting and operating conditions.

In reporting on the noise emission of products, the range of motion should be included, measured in accordance with the American Academy of Orthopedic Surgeons "Method of Measuring and Recording Joint Motion" (AAOS, 444 N. Michigan Ave., Chicago, IL 60611, 1965).

Installation - The three common methods would be as follows:

1. "Suspending" the prosthetic device at the appropriate position in the test environment.
2. "Mounting" the prosthesis to a test fixture apparatus.
3. "Fitting" a test subject - patient with the device.

Fitting may be most appropriate, since this is the ultimate installation procedure.

Due to the nature of prosthetic devices some consideration must be given to temporal characteristics. Generally, this is a function of speed of operation, load, and position of the device throughout the operating range.

In general, noise emitted by mechanical devices tends to increase as a function of speed. Therefore, as a minimum, the noise level produced by the prosthetic device should be measured at the maximal operating speed (as specified by the device manufacturer). The load applied is likely to have an inverse relationship with speed. Therefore, one could test at the maximum rated load.

Since the purpose of this test is to identify offensive sound emitted by the prosthetic device, the combination of speed, load, range of operation and mounting should represent a "worst case" situation which is likely to occur occasionally in actual use. This offers some assurance that the device will not be detectable under most operating conditions, without undue penalty or biasing the results by testing under conditons which are not likely to occur.

Single number rating - The A-weighted sound pressure level should be measured. This rating has been used extensively in noise standards and evaluation schemes. It is an indication of the perceived loudness based on subjective equal loudness contours.

Octave band analysis - For assessing noise emission of the prosthetic device and comparison with criterion levels, an octave band analysis must be performed. This should be conducted at the single measurement position (of maximal noise level) determined above, for the 8 octave bands. This data will provide the necessary information on spectral content enabling a design engineer to establish the most offensive frequency ranges. To do this, one would plot the octave band pressure level as a function of frequency, superimposed on a set of Preferred Noise Criteria (PNC) curves (see Figure 1). These curves were developed in order to provide a detailed criterion for the specification of acceptable noise levels in spaces occupied by human beings. Therefore, if the noise level, as a function of frequency, for typical indoor spaces can be specified by PNC curves, then this provides a convenient goal or criterion for prosthetic device noise emission. If one hopes to avoid detection, then the noise produced by the prosthesis should be below the background noise level in the environmnent. This background noise provides the necessary masking, which prevents an observer from identifying prosthesis noise.

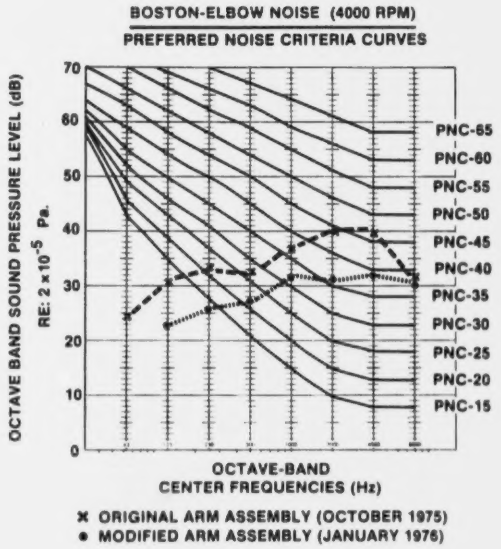

Figure 1

It is suggested that as an initial goal, a PNC of 35 would provide reasonable assurance that the prosthesis would not be offensive in a typical space.

SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 3

COMPUTERS I - ACCESS AND INTERFACES/
ORDINATEURS I - ACCÈS ET INTERFACES

A COMPUTER INTERFACE FOR TETRAPLEGICS USING OPTIMISED ENCODING

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ABSTRACT - For the severely physically disabled, computer keyboard emulators using an encoding principle have a number of advantages over other methods. A compact microprocessor device using optimised two-switch code is described and examples given of its practical application.

RÉSUMÉ - Les émulateurs de clavier d'ordinateur basés sur un principe d'encodage offrent aux personnes gravement handicapées différents avantages que n'offrent pas les autres méthodes. On décrit un appareil à microprocesseur compact utilisant un principe d'encodage optimisé à double possibilité et on en donne des exemples d'application concrète.

The many benefits which those with severe physical disability can obtain from the use of computers are now well established (Bolton 1982). As a consequence a number of groups have produced keyboard emulators working with a single or double switch input to allow the full use of computer equipment by those unable to use a conventional or expanded keyboard (TASH 1983). For high level tetraplegics the most common input is by mouth pressure via a tube to pneumatic switches generally referred to as 'suck-puff' control.

To have a sufficiently widespread application, keyboard emulators should produce their output characters or strings in standard ASCII code via a serial or parallel interface, although it is accepted that simple adapters are generally required to couple the emulator to the computer equipment and these are computer specific. However, the hardware does not present a significant technical problem and the main area of contention is in the method used to select the characters.

The most common and perhaps obvious choice is some variant of the scanning matrix. The character set is presented on a display board or VDU screen and each letter or function is selected by stepping the cursor along on a row and column basis. This principle has the advantage of simplicity and ease of learning but is relatively slow. As a computer interface it has another major disadvantage. If the computer is to function normally, the matrix cannot be displayed on the computer screen. If a separate VDU is used, as in the TASH system, then a constant transferring of viewpoint between the two screens is necessary. This becomes mentally and physically fatiguing with long periods of use. Additionally a separate VDU or display board greatly increases the hardware cost and complexity.

Our work with a number of tetraplegics over a 7 year period led us to consider alternative selection methods. Direct selection with a mouthstick and standard keyboard was successful but users complained of sore necks and the inability to speak at the same time. Scanning matrices were tried with the usual ease of learning but we observed that the users quickly ceased to look at the display. They had unconsciously memorised the co-ordinates of all the common characters and the display board became redundant. They were in practice using an 'encoding' method. Once this was realised we adopted much faster encoding systems, again with great success. Contrary to opinions previously expressed, we did not find that encoding methods required a high level of cognitive ability nor was learning an undesirable process (Cook et al 1983, Buhr and Holte 1981). The time to reach fluency was no different for a 10 year old educationally sub-normal child than for a 21 year old university student. The only factor that appeared to influence learning rate and ultimate transmission speed was amount of use. Therefore, we contend that character selection techniques are associative by nature and there is no hierarchy of cognitive ability as suggested by Cook et al.

With the decision to use an encoding method for computer interfacing, a number of advantages became apparent. Firstly, the hardware could be made very compact and low-cost. Secondly, the user could concentrate on the computer screen, no other displays being necessary, and finally the transmission rate could become faster than other 2 switch systems.

Morse code has been advocated for disabled users (McDonald et al 1982) and indeed is ideal for a single switch input where this is necessary. However, most users can operate a two-way switch and thus Morse loses its advantage. The TWC (Typewriter Control) code developed by R.G. Maling is optimised for a two-way input and achieves a theoretical speed increase over Morse of 2.17 (calculated for frequency weighted alphabetic characters) and an even greater increase when the additional symbols and functions for computer operation are added. Consequently, we have used an extended TWC code for our computer interfacing

(See Table 1).

All the work of decoding, providing the acoustic timing signals and outputting the ASCII data is performed by a small microprocessor-based unit called CID (Computer Interface for the Disabled) (Bolton et al 1982). Output is available in either serial or parallel form and all 128 ASCII codes can be transmitted. The unit measures 19x11x6 cm and is now commercially available.

CID was originally designed for use with mainframe or minicomputers and simply connects between the computer and terminal leaving the latter fully functional. We now have a tetraplegic working as a professional programmer with a multinational oil company using CID coupled to a VAX multicomputer system. However, with suitable keyboard interface units, CID is also in operation with Apple II and BBC microcomputers in the users' homes. Operating speeds of 80 characters per minute are being achieved and the limit has not yet been reached.

Conclusion

Keyboard emulators using optimised 2 switch encoding have a number of significant advantages over matrix selection methods especially where professional or serious domestic use of computers is required. Codes are easily learnt and the process seems to be independent of cognitive ability. A compact, low-cost unit has been thoroughly evaluated by 8 tetraplegic users, including a professional programmer, and is now commercially available.

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LETTERS	
A	S1 01 P
B	P1 03 P
C	P1 02 P
D	S2 01 P
E	P1 S
F	S3 P
G	S1 03 P
H	S1 02 S
I	S1 01 S
J	S3 01 S
K	P2 02 S
L	P1 02 S
M	S3 S
N	P2 P
O	P1 P
P	P2 01 P
Q	P3 01 P
R	S1 02 P
S	P1 01 P
T	S1 S
U	P2 01 S
V	S2 02 P
W	P3 P
X	S3 01 P
Y	P3 S
Z	S4 01 P

L/C	U/C	SYMBOLS
0	0	P2 03 P
1	)	S2 03 P
2	*	S4 P
3	/	P4 S
4	@	S4 S
5	#	P4 P
6	$	S1 04 P
7	&	P1 04 S
8	8	S1 04 S
9	(	P1 04 P
.	.	P1 03 S
,	?	S1 03 S
;	:	P3 01 S
-	!	S2 02 S
'	"	P3 02 S
=	+	S3 02 S
%	%	P3 02 P
<	>	S4 04 S
[	{	S3 03 P
\	|	S3 04 P
]	}	S4 02 P
↑	∿	S4 03 P
—	Del	S4 04 P

Space	S1 P
Backspace	P2 03 S
Hor. Tab.	S2 S
Ver. Tab.	S4 01 S
Line Feed	S4 02 S
Form Feed	P4 04 P
Car. Ret.	S2 01 S
Escape	P4 02 S
→	P1 01 S

Shift	P2 S
Sh. Lock	P4 01 S
Control	S2 P
Sel. Rate	P2 02 P
Cap. Lock	P2 04 P

S = Suck
P = Puff
O = Off

TABLE I Extended TWC Code
(After R.G. Maling)

APPLICATION OF AN OPTICAL KEYBOARD FOR JOB-SITE ACCESS TO STANDARD COMPUTER SYSTEMS

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ABSTRACT - For individuals with severe motor disfunction, access to standard computers and computer systems necessary for some jobs can be difficult or impossible. Special low-fatigue techniques are available, however, which can provide transparent access to computer systems without requiring modification to any system software. Described is one approach now being used at the Government Accounting Office in Washington.

RÉSUMÉ - Certaines personnes souffrant de troubles moteurs sévères trouvent difficile, voire impossible, d'accéder à des ordinateurs ou des systèmes informatiques dont elles peuvent avoir besoin dans leur travail. Il existe des techniques peu éreintantes qui leur offrent un accès transparent aux systèmes informatiques sans que cela impose une modification du logiciel. On décrit ici la solution utilisée au Bureau de la comptabilité du Gouvernement à Washington.

INTRODUCTION TO THE PROBLEM

When I first joined GAO over twenty years ago, I had muscular dystrophy, an increasingly debilitating disease. At the time, it was only a minor impediment to me. I was able to work in the same environment with the same implements as my co-workers. Since that time, I have experienced a gradual, almost imperceptible loss of muscular ability. Today I require a power wheelchair for mobility, and experience fatigue from even light exertion such as typing or writing.

In order to expand job opportunities and reduce hand-writing tasks, I also moved over into the use of the GAO mainframe computers, and tasks revolving around the manipulation and statistical analysis of data gathered for GAO. Fatigue, however, was still a severe problem. Some low-fatigue mechanism was therefore needed which would allow access to the standard computers and computer systems at GAO. This access, however, had to be provided without modifications of any kind to the GAO equipment (leased) or the software systems (which were essentially inaccessible, and under constant external revision as well as use by multiple departments).

THE SOLUTION APPROACH

The approach taken was to develop a special optical keyboard which could be operated with head-pointing motions. This provided a low fatigue and fairly quick input technique. The optical keyboard was coupled with an abbreviation expansion routine to accelerate the effective rate of input. The output of this accelerated optical keyboard was then fed into a keyboard emulator module which plugged into the standard DEC VT-100 terminal (Digital Equipment Corporation). The keyboard emulator made the signals coming from the accelerated optical keyboard look exactly as if they had come from the VT-100's standard keyboard. It is thus impossible for DEC VT-100 or the mainframe computer to tell that the user is not typing on the standard keyboard. The VT-100 was chosen because it is the same terminal line being used by all of the other individuals at GAO. Thus, except for the optical keyboard, this "special terminal" looks exactly the same and functions in exactly the same manner as any of the other terminals in the office. The only actual difference in the operation of the terminal is that an auto-dialing modem was provided for this terminal. The modem is the same brand as used by all of the other terminals in the office. The auto-dialing feature was added, however, to allow the user to call up the mainframe computer directly from the "keyboard" of the terminal, rather than having to manipulate the phone by hand.

Except for two small custom hardware modules, all of the hardware used in the system is standard off-the-shelf hardware to maximize the replication and dissemination of the technique. The two custom modules (the optical headpointer and the keyboard emulator) are both general-purpose modules developed at the Trace R&D Center in Madison, Wisconsin, and are currently being transferred themselves to commercial production.

THE BASIC COMPONENTS

The basic components of the overall system are:

1) long-range optical headpointer.
2) Apple II computer, which provides the optical keyboard image, the feedback of the headpointing position, and the abbreviation expansion routines, and the keyboard emulator driver.
3) keyboard emulator for the proper computer/terminal (in this case, a DEC Model VT-100).
4) standard computer terminal (DEC VT-100) with auto-dialing phone modem.

5) standard mainframe computer running standard software.

The long-range optical headpointer used was developed at the Trace R&D Center at the University of Wisconsin. This pointer is approximately the same size as a magic marker, and works on the same principle as a lightpen. However, special amplification and signal processing is done such that the pointer can be used from as much as four feet from the screen, with one-pixel stability. As a result, the pointer can be attached to the user's head, and very precise feedback of the pointing motions on a television screen provided.

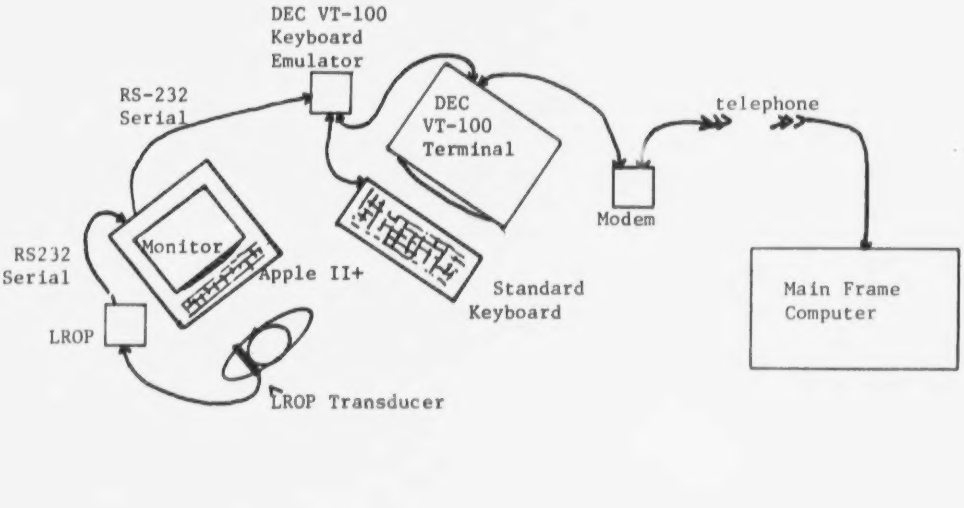
The output of the optical headpointer or lightpen is X and Y position on the television screen; this is sent via RS232 serial ASCII to the Apple (or any other) computer. The Apple computer presents an image of the keyboard on the screen, and moves a spot around the screen to correspond to the position being indicated by the long-range pointer. The effect to the user is as if he or she were pointing to the screen using a beam of light. Using this flowing dot, the user points to the various keys on the keyboard. The Apple computer notes when the user pauses on a key, and accepts those keys as keystrokes. The Apple computer also keeps track of the user's abbreviations and vocabulary. This allows the user to spell out words, phrases, and even commonly used sentences or paragraphs using very short 2- and 3-letter abbreviations. A 20,000-word spelling dictionary is also provided in the Apple to aid users who need but have difficulty accessing standard (paper) spelling dictionaries.

The output from the Apple then goes to the keyboard emulator module. This module accepts RS232 serial ASCII and puts out electrical signals which exactly emulate the signals from the VT-100's keyboard. The KEI (Keyboard Emulator Interface) Compatability Standard developed at the Trace Center is used to handle the codes for the non-ASCII keys on the VT-100 keyboard.

The rest of the system is standard terminal and computer hardware, and is used in the standard fashion.

CONCLUSION

As computer technology becomes more deeply involved in the workplace, technology can become either a means for helping handicapped persons or become another, perhaps even greater, barrier to their participation. The specific equipment and the general approach described show how it is possible for those with limited or no use of their hands to interact with and control standard computer hardware and software. This can open doors to both employment and social participation, and help disabled individuals realize their full potential.



EXPRESSIVE COMMUNICATION, COMPUTER ACCESS, MOBILITY AND ENVIRONMENTAL CONTROL IN AN INTEGRATED SYSTEM

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ABSTRACT - Under contract with tne U.S. Department of Education, Prentke Romich Co. is demonstrating a system of technology for use by handicapped students in the classroom. The project includes development, assembly, evaluation and the preparation of a marketing plan.

RÉSUMÉ - Dans le cadre d'un contrat passé avec le Department of Education des États-Unis, la Prentke Romich Co. fait la démonstration d'une technologie destinée à un usage en classe par des étudiants handicapés. Le projet comprend la mise au point, le montage et l'évaluation du système et la préparation d'un plan de commercialisation.

BACKGROUND

In the public school system today, a great number of students are being excluded from the education process. Generally, these children are present in the classroom, but their inability to communicate effectively and to interact with the educational environment puts them at a disadvantage. They cannot interact with their teachers and peers because they cannot speak and are physically impaired to the degree to be unable to use writing, typing, sign language or gestures. However, when provided with appropriate technical aids, these children can frequently excel educationally. Without aids many of them will go nowhere.

Three important needs of this population are:

1. Communication,
2. Access to computers and
3. Mobility.

It is generally agreed that the priority of importance is in this order, even though the priorities may still be reversed by some funding agencies.

Much work has been done to address the needs in each of these areas. However, very little has been done to integrate these areas of need. For people with less severe levels of impairment, integration is not necessary. These people have enough physical capability to be able to use the conventional solutions to the separate problems. But people with limited capabilities may only be able to use one technical aid. For example, since a person's level of achievement is closely tied to the ability to communicate, it makes sense to use the total physical capability toward that end. The system described here provides for the control interface and expertise developed in the communication task to be applied to these other areas of need.

SUPPORTING WORK

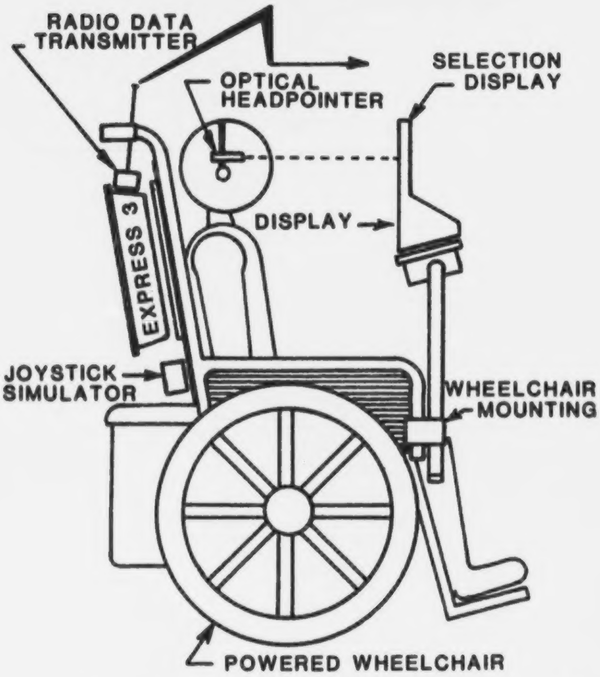
Several years ago, the Rehabilitation Engineering Center team at the University of Tennessee in Memphis developed the optical headpointer for a student at the Shrine School, Lainey Marty. Lainey's primary need was effective communication. Prior to this development, Lainey had to use what, for her, were much slower and less effective techniques, such as row-column scanning, eye encoding, and a headstick. The optical headpointer technique was successful for Lainey and has since become commercially available. The Trace Center at the University of Wisconsin in Madison more recently suggested and helped develop the hybrid pointer system which combines the optical headpointer and a light beam for visual position feedback, making the technique useful for a greater number of people.

After completing an initial communication system for Lainey, the UTREC staff addressed her mobility needs. Wanting to take full advantage of Lainey's expertise with the optical headpointer, they added a DRIVE mode to her prototype system, which now also includes an output for connection to a computer. The system being reported here has grown out of Lainey's needs and has come to be known as The Lainey System. However, other implementations are expected to be developed to accommodate people with other capabilities, such as keyboard entry, joystick, arm slot control, and even single switch.

SYSTEM DESCRIPTION

The line drawing shown here indicates the placement of the major components on the powered wheelchair. Other components related to the stationary computer and environmental control system are not shown.

THE LAINEY SYSTEM



The core component of The Lainey System is an expressive communication aid. For this project, the Express 3 was chosen because it contains the major features needed to satisfy most communication needs, can be operated using optical headpointing, as well as many other techniques, and offers the versatility to move into the future. As of this writing, the decision has been made to provide Lainey with the Minspeak, to which the Express 3 can be updated. The microprocessor base of the Express 3 permits such improvements and allows for accomplishing the integration of this system with relative ease. The Express 3 is mounted behind the wheelchair. Cables and a wireless link connect the Express 3 to the various other components:

Selection panel (or other control interface),
Joystick simulator,
Computer and
Environmental control.

The transparent selection panel offers some view of the environment for the purpose of improved mobility. It contains a remote single line correctable display for user feedback. The operating program in the Express 3 was modified to accept selections from an external device. This also permits the use of a remote keyboard where having the bulk of the Express 3 in front of the user is undesirable.

The joystick simulator connects to the original powered wheelchair control package in place of the original joystick. Use of the original power control components was selected to minimize the cost and facilitate service by local dealers. The joystick simulator accepts information from the Express 3 and provides input to the power controller.

Computer access is accomplished through a wireless data telemetry system. The transmitter is connected to the Express 3 and the receiver is connected to a computer keyboard emulator.

Environmental control, while not a priority of students in the classroom, is important at home. With the standard Control 1, reported at RESNA '83, comprehensive environmental control is inherent in the computer access capability. Using the wireless telemetry, for example, the user in his living room could transmit a code to the Control 1 in the bedroom which in turn transmits over the power line to the BSR power module, turning on the stereo beside him.

EVALUATION AND MARKET PLAN DEVELOPMENT

Evaluation of The Lainey System is to be performed at the University of Tennessee Rehabilitation Engineering Program and at the Shrine School in Memphis. As of this writing, evaluation and market plan development have not been started.

COMMERCIAL AVAILABILITY

Prentke Romich Company plans to make this system commercially available and to continue further development in this area.

This project is a joint effort between the United States Department of Education and Prentke Romich Company.

THE JOYWRITER, A COMMUNICATION AID FOR THE SPEECH IMPAIRED AND MULTI-HANDICAPPED PERSON

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ABSTRACT - This paper describes the human factors design of a software communication package for severely disabled persons with a speech impairment and severe motor involvement. The process described is applicable to the design of many systems in rehabilitation.

RÉSUMÉ - La présente communication décrit la conception des facteurs d'adaptation humains d'un progiciel de communication destiné aux grands handicapés ayant des difficultés d'élocution et de graves troubles moteurs. Le procédé présenté s'applique aussi à la conception de nombreux systèmes de réadaptation.

INTRODUCTION

A survey of manufactured communications aids for persons having speech impairment with manual complications reveals a myriad of hardware and software solutions that too often are too cumbersome, too complex, too expensive and often inappropriate for many persons who need them. The authors set out to design a communication package with the assistance of many of these persons who have no alternative to the speech they lack at present.

The experience with designing a hardware based portable communications unit in previous years had taught the authors several points: the system must be portable enough to be used by persons in wheelchairs, it must be inexpensive in its final marketed form, and it must be easy to use and easy to learn to use. In addition, it required a highly visible display and a flexible, as well as versatile, control interface.

These hardware considerations were the result of three years work in perfecting a Morse-code based low cost portable communicator. The work has been invaluable in providing basic and essential information after five man-months of actual field testing by persons whose only alternative was a letter board.

THE INITIAL PROBLEM

With that background this team received a new challenge - a patient whom we will call "John", referred by Occupational Therapy. Hehad the use of only two fingers. He had a previous history of severe traumatic brain damage and had for two years been unable to communicate by his own volition. His communication was limited to "twenty questions" which he answered by raising one or two fingers. This was extremely unsatisfactory since his answers lacked consistency and it was unknown, and therefore debated, whether he had actual extreme loss of cognitive ability, or was amusing himself by giving bizarre answers to questions during tests.

The previous Morse-code communicator was inappropriate since the patient had no knowledge of Morse and it was highly questionable as to whether he could be taught. A system was needed that was so simple and obvious in its use that he could begin using it with his limited ability immediately.

THE SYSTEM

The Joywriter was the result. It is a communication package that emerged from, at first, the needs of one patient and grew to encompass the needs of many.

Hardware

For convenience of the authors and for reasons of flexibility, versatility, and to some extent, standardization with the work of others, the authors chose the Apple II family as the computer on which to implement a software model of the initial system. The minimum "starter kit" of an Apple II family computer, one disk drive with controller, and a monitor is required. In addition, a standard Apple peripheral joystick is also required. The type joystick without springs is preferred for this application. DOS 3.3 is essential along with 64k of memory. A printer and printer interface card are optional but desirable.

Software

The software was developed on the Apple II Family computer in GraFORTH, a graphics language written by Paul Lutus for Apple Computer Inc. This was chosen because of its enormous speed, flexibility, capability to easily mix text and graphics, and a vocabulary of programming commands - or words - that can be invented and expanded by the programmer. This vocabulary is vital to the custom-tailoring of the main program for each user.

An initial program was designed that was simple and extremely easy to use. It was intended as a "jumping off" point in the ultimate design and yet it proved to be an extremely useful tool.

The joystick and the two push buttons, PB 1 and PB 2, are all the user requires as a control interface. The software is menu driven and utilizes expanded print sizes to accommodate patients like John who may have a functional visual deficit due to an inadequate motor control of the focusing muscles in the eye. We determined through testing that John required the larger letters of four times normal size to read them easily.

The program is designed to be modified according to the specific disabilities and limitations of each user.

The joystick is used to select each character the user wants to print on the screen. The standard joystick is bounded by a four sided square. Starting at a predetermined corner of this square, the joystick slides in a clockwise direction along each side. As the joystick moves, its (X) and (Y) coordinates change. The program has a table written into it. As the coordinates of the joystick change, the program selects a corresponding character - a letter or number.

That character is displayed in the top left hand corner of the screen. It is two inches high, (on a 12 inch monitor) and may be made larger or smaller as necessary.

When the user slides the joystick to a point where the required character is displayed in the top left corner of the screen, the user presses push button one, PB 1, on the joystick unit. The character is then printed on the screen. The joystick is then moved to select the next required character. This mode is called the Writing Mode of the program.

```
A B C D E F G H I

<               J

$               K

HI      .       L

>               M

Z               N

Y               O

X W V U T S R Q P
```

Note: 1. > is a space key
2. < is a backspace/correction key.
3. HI is a prewritten word, viz. "HI".
4. . at the center of the square is a period. Other syntax symbols can be added at the particular patient's request.
5. $ is also a prewritten word, of the patient's choice. For the demonstration disk, the patient chose to print the word "FANTASTIC" whenever he selected $.

TABLE 1.

The characters include the letters of the alphabet, a backspace character and a forward-space character. (See Table 1.)

The choice may additionally include numbers and pre-written words such as "Hello", or "I am hungry."

The other push button PB 2, may be called the "MODE" button. This button allows the user to select menus of possible alternatives. This capability evolved after the initial program described here.

The program printed each character selected by the joystick on the screen and gradually built strings, or sentences out of these characters as the user chose each letter by pushing PB 1. The sentences could be easily read by anyone viewing the monitor.

It was this program that we introduced to John and we found that he could indeed learn to use it quickly and was actually able to write his name after limited practice. He indicated answers to questions with a "Y" for yes and "N" for no, which appeared to be more reliable than his one finger, two finger system.

Another user, "Gloria" was introduced to the system at this point. Gloria had a history of Friedreich's Ataxia, and though she was known to have extremely good mental abilities, had less volitional control. In fact, she had so little control that she could not let go of the joystick and push the button to enter letters. The program was quickly modified to provide a timing loop that only required her "dwelling" on a letter for three seconds for it to be entered. She had good motor control in so far as her precision with the joystick itself. This simple modification provides a capability for the same program to be used by differing patients by a simple selection of a subroutine.

Work continued and we found that Gloria and a new patient, "Monte", required the ability to print out their work, or save it to disk, or to even edit to write letters, etc.

Monte has cerebral palsy and has had two strokes which further limit him. He has, however, been a star student of the Joywriter. He readily learned to use the push button two, PB 2, to select modes for printing out his work and saving it to disk. When a file is saved to disk or printed out, it carries with it the patient's name, date and a file name.

EXPANDING THE SYSTEM

Printouts and Text files

At any time, the user can print out what has been written, or save it as a text file on the program disk. To do this, the user presses the "MODE" button, PB 2. The screen clears and displays everything that the user has written so far. The screen also displays a menu:

"Press button one to <1> Printout
                     <2> Use disk

"Press button two to write more."

If the user presses the "MODE" button, the program will return to the Writing Mode in which each character is selected and printed.

If the user presses button one, the screen clears and a new choice is displayed:

"Press button one to Printout
Press button two to Use Disk."

If the "one" button is pressed, the screen clears and a new set of choices appears, allowing the user to choose between printing out what is written or returning to the Writing Mode. If the printout is selected, the text is printed out, under a heading that includes the user's name, the date and the page number. Once the hard copy is printed, the computer returns to the Writing Mode.

If the "two" or MODE button is pressed, the screen clears and a new set of choices appears, letting the user choose between reading what is already in the user's text file or writing the latest text to the text file. Once the text file is either read or written to, the computer returns to the Writing Mode.

At each point in the tree structure of the program, the user has an option to return to the Writing Mode of the program.
The tree then provides for the following functions:
Writing, Printing, Reading Text file, or Writing to Text file with an option at each point to return to the Writing Mode.

The Text file bears the name of the user and can be processed at any time with many word processor programs using text files such as Applewriter II or Applewriter IIe.

The system does provide the user the ability to write his own programs if he chooses. The program may be written to the text file in either BASIC or GraFORTH, and run with the EXEC command for BASIC, or from the GraFORTH system.

USER TRAINING:

Experience to date with this package has shown that an hour's training is sufficient to teach the capabilities of this package. Much of that introductory period involves actually clamping the joystick unit into the most convenient position for the user. None of the user's had ever had computer interaction previous to this training.

CONCLUSION

The Joywriter system while successful as a communication package as it is has enormous and fast developing potential. It can, of course, be readily modified to accommodate other control inputs than the joystick and momentary contact switches provided by manufacturers of Apple peripherals. Any two axis control interface with two additional switches is applicable with resistance values adjusted to compensate for the 150k ohm input required for accurate reading by the Apple.

That is a limited view however. The system is now being reduced to an Assembly language program for the Intel 8748 one chip microcomputer system. This is being installed into the old Morse Code Communicator to provide an easy-to-learn, easy-to-use portable communicator with many options. A menu can permit user access to a message library of user programmed phrases and messages.

This approach of designing, software first followed by hardware implementation, has proven to be a low cost and highly effective method of determinining an optimal human factors design. Minimal changes are required in hardware and several software options may be offered either in the form of a user selection or by having interchangeable program chips prescribed by a therapist.

The results already consist of a software package free to any who send a blank disk, and ultimately a portable hardware device that will contain many of the same features and options. This upward compatibility is unique in communications systems development and opens a new world to those who most need further horizons.

Persons who have until now felt their unimpaired intellect and self esteem bound in by physical disabilities can reach far beyond the strictures of the wheelchair or bed by assisting in writing programs to make computers do precisely what they want, in a fashion which only they can fully appreciate and experience.

TWO HEADPOINTING INPUT TECHNIQUES - A COMPARATIVE STUDY

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ABSTRACT - An ongoing empirical study comparing two headpointing technologies is described. Details of subject selection, research methodology and design and the configuration of the research instrument are provided.

RÉSUMÉ - Une étude expérimentale en cours, comparant deux technologies qui sont en train d'émerger, est décrite ci-après. On y donne les détails relatifs au choix du sujet, à la méthodologie et à la conception de la recherche, et à la configuration de l'appareil de recherche.

Background

For several years the Trace Center has been interested in developing and comparing input methods using the head as the bodily control site for input to a communication aid or computer. This interest grew out of clinical experience indicating that clients with athetoid cerebral palsy were much more accurate when pointing with an optical indicator than one might think when observing their use of a mechanical pointer (head stick or mouth stick).

Development efforts have resulted in the hybrid optical headpointer for the Express III (HPS-1, Prentke Romich Co.)[1] and in the LROP (Long Range Optical Headpointer; Gunderson, 1983)[2].

In 1978 Polhemus Navigational Sciences, Inc. developed an electromagnetic head tracking device, called the SPA-SYN, used by military personnel to aim weapons at targets. A 3-dimensional head position sensor and a sighting device is mounted on a gunner's helmet, and the target location is derived from the gunner's head position when the gunner looks at the target. Application of this technology to control computers for the handicapped seemed possible, the largest barrier at that time being portability and end-user expense (Schneider, 1982)[3].

Project History

P.N.S.I. (Polhemus) received funding from the Veteran's Administration in 1981 to act as contractors in developing the SPA-SYN technology as a prototype aid (SPA-SYN-COM). The Trace Center has been conducting an empirical study to determine which of several headpointing technologies and techniques work best for handicapped users.

At this writing, the project is in Phase II, the evaluation and testing of the various methods of headpointing or headpositioning. Twenty disabled subjects have been selected and pre-screened. They will play a series of video "games" which use different algorithms both in interpreting the pointing motion of the subject and in providing various types of feedback to him/her. (Subject testing is scheduled to begin in January, 1984.)

Activities to date have included developing a statistical approach and research design for the experiment, physically configuring the research instrument, and writing the software necessary for data collection, games protocol, targeting, etc.

Research Design and Analysis

The population of interest includes those individuals from age 8 to adult for whom: 1) speech is not a functional communication system or 2) access to keyboard devices is limited due to paralysis, weakness, incoordination, or absence of the upper limbs. Further, the population of interest is defined to include only those candidates for augmentative communication who attain satisfactory performance on a pre-test of head control.

Persons in this population exhibit widely varying degrees of involvement with their particular disability.

The impaired motor functions (which may or may not interfere with speech, but which do affect the control of the arms and hands in all of these people), can be divided into three categories. These categorical divisions are:

1) absence of control (paralysis, polio)
2) reduced effectiveness of control (myasthenia gravis, ALS, MS, other degenerative neuro-muscular diseases)
3) interference with control (athetoid, spastic or atonic cerebral palsy)

Data analysis will look at differences both within and across the three groups, employing the

Wilcoxin One-Sample Signed Ranks test .

A nonparametric statistical test was chosen because the assumption of normalcy was inappropriate for this population. There is no basis for believing that the distribution of performance scores even among all subjects with athetoid cerebral palsy (e.g., the same "group" in this study) will approximate a bell-shaped curve. The signed ranks test gives the greatest opportunity to capture existing trends in the data, even with large absolute inter-subject differences in performance scores. Such individual differences will not tend to cancel each other out using this method of analysis.

Two types of algorithms providing feedback to the user will be tested with each headpointing technology, actually giving four differently implemented tasks. One algorithm will include hysteresis, a simple way of averaging the user's continuous motion about the target. One will provide only direct interpretation of the user's pointing motions. The presentation order, and the sequencing of orders across 8 days of testing is randomly counterbalanced across subjects (twelve of the possible permutations of the four orders are randomly assigned to the 24 subjects.)

Subjects

The prevalence of the types of severe disabilities of interest in this study is relatively low in the general population, so that the distribution of potential volunteer subjects makes random selection logistically impossible. Nonetheless, the authors believe that 1) results both across subjects within groups, and 2) differences between groups will reveal relevant similarities. The authors maintain that these subjects are enough alike in their performance to be considered "typical" of their population group. Only replication of this study elsewhere will validate the assertion, however. Local subjects in Madison, Wisconsin, a group of several subjects at Gunderson Clinic in LaCrosse, Wisconsin and a group of 15 institutionalized children at the Illinois Childrens School and Hospital in Chicago will comprise the 20-24 subjects.

Research Instrument

The research instrument, which is based on the IBM Personal Computer, requires 2 serial input/output ports, a color graphics adaptor capable of 4-color medium resolution graphics, 576K bytes of memory, and 2 high-capacity disk drives. A 19" color monitor is used to present the targeting task. The software was developed in the language FORTH.

Data Collection

A computer program has been developed for capturing position and movement patterns of individuals using the long-range optical headpointer and the SPA-SYN device. The program presents the subject with a targeting task which simulates the process of selecting a word from a communication board. The communication board is represented by a grid on a color TV monitor. All but one of the cells in the grid contain the same object (foil). The cell containing the different object (target) represents the letter that the subject is trying to select. "Targets" and "foils" are not linguistically loaded, so that their use does not introduce confounding variables related to age, reading skill, or cognitive functioning. As the subject selects the target, the program moves the target location around the grid in a fixed pattern. Selection of a foil causes the target to appear in the center of the grid. This forces the subject to select the center cell when an error is made so that the "backspace" function is simulated. While the subject is playing this video game, the spacing of the cells of the grid changes so that information transfer rate is maximized. The information transfer rate (CITR) is computed as:

$$\mathrm{CITR} = \mathrm{Rc} * \log_2(N)$$

where CITR = corrected information transfer rate
Rc = (S-2*I)/T
S = total selections made
I = incorrect selections
N = available selections
T = time to make S selections

The program saves the following data each time a selection is made:

1. Target/foil selected
2. Number of foils selected
3. Number of targets selected
4. Time since last selection
5. Cell spacing

Results

By comparing these two headpointing technologies, we hope to quantify the trade-offs implicit in the further development of either system. The Long Range Optical Pointer requires a CRT display. High resolution LCD displays, however, are becoming standard on portable, battery-operated computers. The SPA-SYN technology could be used with the LCD displays, and could even provide active feedback. A limiting factor to further development of the SPA-SYN-COM at this time is probable end-user cost. The results of the current study will guide further development decisions so that resources can be directed to provide maximum benefits.

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GENERIC KEYBOARD EMULATOR ARCHITECTURE FOR TRANSPARENT ACCESS TO STANDARD SOFTWARE BY HANDICAPPED INDIVIDUALS

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ABSTRACT - One very powerful method to allow handicapped individuals to access computers and standard software is the use of keyboard emulators. Different computers, however, use widely varying technologies, necessitating emulators which operate quite differently electrically. It is possible to capitalize on the functional similarities of the emulators to minimize the redesign necessary to create new emulators.

RÉSUMÉ - Les émulateurs sont des outils très puissants permettant aux handicapés d'accéder seuls à des ordinateurs et à du logiciel standard. Toutefois, il existe de nombreux ordinateurs différents qui font appel à un large éventail de technologies; il est alors nécessaire d'avoir des émulateurs dont le fonctionnement électrique est passablement différent. Il y a possibilité d'exploiter les similitudes fonctionnelles des émulateurs pour alléger la tâche de reconception des émulateurs.

INTRODUCTION

One of the principle difficulties in the use of computers by individuals with disabilities revolves around their inability to use standard computer software and operating systems. Although special software can be written which can accomodate any specific handicap, access by handicapped individuals must also be provided to the vast wealth of standard unmodified software. This is necessary both to provide access to the functions implemented in these standard software programs and to allow handicapped individuals to be integrated into regular education, work, and living environments which utilize computers and computer systems with standard software packages.

Currently, the most powerful technique for allowing access to standard software by individuals with physical handicaps is the keyboard emulator. The keyboard emulator is a module which connects between the computer's keyboard and the rest of the computer. The emulator itself does not interfere with the use of the standard keyboard in any way. It does, however, allow "keystrokes" to be sent from special communication aids, which it then passes on to the computer. The method it uses to pass the characters to the computer is such that it exactly imitates the standard keyboard's electrical signals. Since the emulator is plugged into the same point as the standard keyboard, the computer is completely unable to distinguish keystrokes being sent from the standard keyboard from those coming from the keyboard emulator. As a result, all input to the computer from the special device is exactly equivalent to keystrokes on the keyboard. All software written to operate with the computer's standard keyboard can therefore be operated by handicapped individuals using any one of a wide range of adaptive communication or control aids.

THE PROBLEM

Because the emulator must exactly imitate the keyboard, however, the emulators must be electrically tailored to exactly match the characteristics of the keyboard for each specific computer they are to be used with. This tailoring includes both electrical and physical modifications. As a result, keyboard emulators generally need to be designed separately for each computer. Even the Apple II and the Apple IIe require different keyboard emulators, since they have keyboards which are electronically different. As a result, there are relatively few computers for which keyboard emulators are commercially available, and the delay between the introduction of a new computer and the availability of an emulator for it can be quite lengthy.

THE APPROACH TAKEN

In order to alleviate this problem, to provide a mechanism for more timely development of new keyboard emulators, and to provide a mechanism for lower-cost development of keyboard emulators for new computers, a program was initiated to develop a generic architecture for keyboard emulators. This approach consisted of two parts:

1) the development of a single-chip, microprocessor-based emulator architecture which could be easily adapted to create keyboard emulators for new computers as required.

2) the development of a standard code for communicating with keyboard emulators and handling keyboards having differing numbers of keys and a variety of special non-ASCII keys.

The emulators themselves are all designed to take is done to maximize their ability to be used with a wide variety of communication and adaptive control aids. The output of the emulators, as well as their packaging, is customized for the particular computer being used. For computers with external plug-in keyboards, such as the IBM PC and the DEC VT-100 series terminals, the keyboard emulator is packaged in a small plastic box which plugs in between the keyboard and the CPU. For computers with built-in keyboards, such as the Apple and the Atari, the emulator is usually put on a small PC board which mounts directly inside the computer.

THE GENERAL HARDWARE ARCHITECTURE

The largest problem with keyboard emulators is the extremely wide variety of communication formats which exist between a computer and its keyboard. In an Apple II+, for example, this format consists of an 8-bit parallel bus with a separate reset line. In an Apple IIe, it consists simply of a shorting of row and column lines in a large 8x10 matrix, plus 6 additional lines. In other computers, an x-y matrix is again used, except that it is read both in an "any key down" fashion, with all lines tied low, as well as individual row-column combinations. The IBM keyboard actually has its own microprocessor and communicates with the main computer using a clocked serial line. The DEC VT-100 terminals also use a serial line, but with bi-directional communication and power being carried on a simple 3-pin connector.

In order to accomodate these widely varying hardware formats, an architecture was required which was very flexible, especially the interface with the computer. At the same time, these various keyboard emulators all were performing the same basic function, and therefore had many functional sub-components which were identical. Rather than using a discrete component approach, as had been used in all commercial keyboard emulators to date, the project opted for a single-chip microprocessor-based approach. This not only allowed for much more flexibility in the design of the emulators, but also provided the processing necessary to handle the multiple simultaneous non-ASCII key closures which are required on many of the newer computers. (For example, the new IBM requires a control-scroll-lock to break from a program, a control-alternate-delete to reset the computer, etc.)

The 8748/8035/8049 family of microprocessors was chosen for the application, due to their widespread availability, low cost, and availability in both MOS and, more recently, in CMOS versions. Each of the emulators uses the same input circuitry (for interfacing to communication aids), the same input software routines, the same translation tables, and the same multiple simultaneous key activation routines. Only the packaging and the electronics to actually the emulate the key closures (and the multi-plexing of the standard keyboard, where required) need be redesigned for newer keyboards. Although these aspects are not trivial, reducing the keyboard emulator design to these components can considerably reduce the design time for keyboard emulators for new computers. In one instance, a keyboard emulator for the Apple IIe was designed and taken through finished artwork in about 6 weeks, and mailed directly to a company that put it into commercial production.

DEVELOPMENT OF A KEYBOARD EMULATOR COMMUNICATION FORMAT

The second aspect of the project was to develop a standard format for communication between the handicapped user's aid and the keyboard emulator. The major problem arises from the fact that the communication aids only put out the standard ASCII characters. Most computer keyboards, however, have many non-ASCII keys. Included are such keys as "SHIFT", "FUNCTION" keys, "SCROLL LOCK", "ARROW" keys, "RESET", etc. As a result, it is not sufficient for the emulators to simply accept ASCII characters and "depress" the corresponding key on the keyboard. Some mechanism was needed to specify these non-ASCII keys as well.

In order to handle this, a special standard communication format was developed in conjunction with the Standards Project at the Trace Center. An ESCAPE sequence was used to specify the names of these other, non-ASCII, keys. Those keys which appear on a large number of different keyboards (e.g., back arrow, delete, shift, etc.) are given standard names. This is done so that an individual can move his or her communication aid from an IBM to an Apple to an Atari, etc., and activate the equivalent key on these keyboards even though the legend on the key may vary slightly. For those keys which are strictly unique to a given computer, the legend on the key is used. Provision is also made so that the keyboard emulator can be instructed to hold down multiple keys while other keys are struck. For those communication aids which have custom vocabulary capability, the entire key sequence for any of the special keys on the computer keyboard could be programmed into a single square on the communication aid; thus, selecting a SCROLL LOCK or RESET square on the communication aid would cause the appropriate sequence of codes to be sent to the keyboard emulator, which would result in a simulated depression of the SCROLL LOCK key or the CONTROL-ALTERNATE-DELETE keys (for reset) on the computer keyboard.

CONCLUSION

So far, the architecture has worked well, and has been used to develop keyboard emulators for the Apple IIe, the DEC VT-100, and the IBM PC. Emulators for the Atari, Commodore, Acorn, and PCjr are currently underway.

A MULTIPURPOSE STAND ALONE EXPANDED KEYBOARD FOR THE DISABLED

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ABSTRACT - Passive matrix type expanded keyboards are reviewed and the development of a multipurpose stand alone matrix keyboard is described. The circuit and mechanical construction is explained and the use with the Trace Center's BLISSAPPLE program is described.

RÉSUMÉ - On revoit ici des claviers matriciels passifs surdimensionnés, et on décrit l'élaboration d'un clavier matriciel autonome à vocation multiple. On présente la configuration mécanique et électronique de celui-ci, de même que l'utilisation du programme BLISSAPPLE du Trace Center.

Introduction

A number of expanded keyboards have been developed in the past in the Rehabilitation Engineering Laboratory in the School of Rehabilitation Medicine at the University of British Columbia. The principle of the design of these keyboards is as follows:- a series of vertical bronze rods is stapled to a 3/4 inch plywood baseboard and foam rubber sheet is glued between these rods. A plastic cover rests on the foam and on the back of this cover is a second set of bronze rods, this time running horizontally. Pressing on the top plastic cover depresses the foam and allows the rods to touch. A grid of appropriate symbols is silk screened on the top of the plastic cover and connections to the two sets of rods are brought out to a suitable plug. These expanded keyboards have been built for a number of devices including the Apple II+, the Apple IIe, the Timex/Sinclair 1000, the Casio organ and the Texas Instruments Speak and Spell, Speak and Read and Speak and Math series. A special expanded keyboard called the Activity Board was also developed for use with electric toys. The thickness and width of the foam which separates the crossed rods can be varied to determine the sensitivity of the switch contacts. The very small contact area and corresponding high contact pressure, creates an efficient self cleaning switch. This keyboard design has been reported earlier (References 1 - 5) and has proved to be very reliable and noise free.

The BLISSAPPLE program, developed at the Trace Research and Development Center allows handicapped children to communicate with Blissymbols. The vocabulary is completely user determined from a library of over 1,400 pre-programmed symbols and selection of the symbols can be made by a variety of different input methods. In most of the cases the Blissymbol is identified by a number, requiring the user to enter this number by one of the input methods. If the user is accessing 500 symbols, then he must either remember the number (of up to three digits) associated with the symbol or must look it up before he can enter it. A common way of achieving this is to have a 500 square Bliss board within visual range of the user. The numbers associated with the symbols are then written under the symbols on this board. Because the board is large it cannot be placed very close to the user, making the numbers difficult to read, particularly by persons with below normal vision.

Preliminary work

The BLISSAPPLE program has a provision for direct access to the symbols from a matrix type keyboard. A circuit to scan the matrix can be built on a plug-in card and inserted into an Apple computer peripheral expansion slot. This circuit must either provide access to the Apple buss or must in turn be connected to a parallel interface card, using up yet another expansion slot. Such a system with 220 squares was built at the School of Rehabilitation Medicine at the University of British Columbia and has been in use at the Vocational and Rehabilitation Research Institute in Calgary, Alberta for the past year. This board uses a 16 X 16 folded matrix of bronze rods on one inch centers, giving a 22 by 10 array on a board 14 inches by 28 inches and 3/4 inch thick.

Present work

Considerable discussion between the authors spanning a period of a year has led to the decision to produce a stand alone expanded keyboard. This keyboard has 512 squares on 7/8 inch spacing using a 32 X 16 matrix. The mechanical construction of the keyboard has not be changed from the earlier versions, however the electronic concept has completely changed. The earlier versions, described in the references and the first version of the expanded Bliss board, all consisted of a simple matrix inside the board, requiring no power to the board. All the electronics was contained in the host device. In the new design, all the electronics is contained inside the expanded keyboard which produces an output of serial ASCII on a standard RS 232 connector. With the advent of small battery operated computers, the expanded keyboard can be used for very many uses other than for just the access to the BLISSAPPLE program. Also if the keyboard is available, it will stimulate others to write programs similar to the BLISSAPPLE for the small portable computers.

The circuit

This was entirely the work of Dave Kelso and is a CMOS system based on an 80C35 microprocessor and a program stored in a 27C16 EPROM. It operates from virtually any commercially available power supply module, either AC or DC from 6 to 30 volts. On later models it is planned to include a battery compartment to allow the unit to be operated independent of an external power supply. The whole circuit is mounted on a 2 inch by 14 inch board which fits inside the expanded keyboard. Connection to the host computer or device is achieved by means of a standard RS 232 interconnect operating at 1200 baud. The 27C16 EPROM can be programmed with numbers, words or phrases or even commands. In the case of the Apple computer, the user must have a serial card plugged into one of the peripheral expansion slots to accept an RS 232 input from the expanded keyboard. Many of the new battery operated computers such as the Radio Shack Model 100 or the Epson HX 20 have built in RS 232 input circuitry. For use with the BlissApple program a keyboard with 512 squares is used. The EPROM is programmed so that the top left corner of the matrix sends a 1 and a carriage return and a line feed, the next square a 2 and so on reading from left to right and top to bottom so that the bottom right hand corner sends 512 and a carriage return and line feed. An overlay with the required Bliss symbols is placed on the keyboard and the squares programmed accordingly.

The expanded keyboard is available from:-
FKEG Electronics Co Ltd.,
P.O. Box 46199, Sta. G.,
Vancouver, B.C., Canada, V6R 4G5
(604) 685-7817

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The British Columbia Health Care Research Foundation (keyboard)

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THE MOD KEYBOARD: NEW PROPORTIONAL INPUT AND DISPLAY TECHNIQUES

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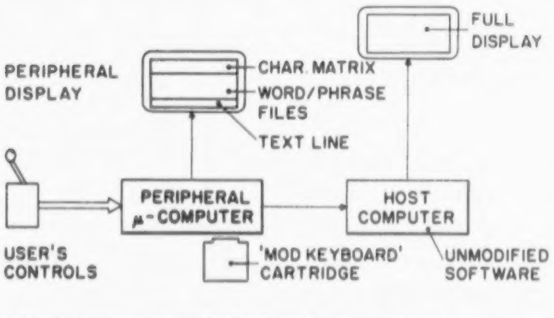
ABSTRACT - To be truly useable by disabled persons, a proportional input device must be linked with a display cursor which moves in a correspondingly proportional manner. A smoothly moving cursor has been implemented on the MOD Keyboard, opening the possibility of using many different input devices; and even of using conventional switch inputs in more effective ways.

RÉSUMÉ - Pour qu'un appareil puisse véritablement être utilisé par une personne handicapée, il doit être doté d'un organe d'entrée proportionnelle relié à un curseur de visualisation qui se déplace d'une manière proportionnel. On a mis au point un curseur à déplacement régulier pour le clavier MOD qui permettra d'utiliser de nombreux organes d'entrée différents. Il permettra aussi d'utiliser de façon plus efficace les commutateurs classiques.

Introduction

The MOD Keyboard is a novel concept in providing severely disabled persons with access to standard computer systems and all of their standard software. It is intended for those who are unable to use a standard computer keyboard, or at least to use it effectively. Now available commercially in a directed scanning version, the MOD Keyboard has been described previously (1).

The significant features of the MOD Keyboard concept are that it displays an alternative computer keyboard, in effect, on the screen of a second, low-cost computer; together with pages of user-definable words, phrases, and computer commands. See block diagram. This approach is based on the use of a very inexpensive peripheral microcomputer...the Commodore VIC-20(tm). The MOD Keyboard is developing into a "family" of interchangeable plug-in cartridges, each designed to accommodate a different type of a disability or a different type of host computer. The design of output variations to support different host computers is described in another paper (2). This paper will describe new "proportional" input techniques.



Block diagram of MOD Keyboard concept.

History of Proportional Input

The search for a proportional input device was originally prompted by a desire to meet the needs of quadriplegics and others with a very high level of paralysis, but with good control of head motion. Various light-beam pointing devices have been developed by ourselves and others, over the years, which provided "direct selection" of characters from a remote display simply by training the spot of light on the desired character. Typically, the light-beam pointer was mounted on the user's head. About 8 years ago, Vasa and Lywood constructed a mouth-operated position transducer with a separate display consisting of a back-lighted character-matrix board (3). The display could be positioned separately from the mouth transducer for best visibility and user comfort.

When it comes to implementing a position-proportional input with an electronic display, Vanderheiden has made some pertinent observations (4). He points out that a display which contains a limited number of discrete targets, such as a matrix board of LED's, provides insufficient feedback to a disabled person about the exact position of the input transducer at any given instant. The earlier devices which used a light-beam pointer were actually easier to operate because the spot of light moved smoothly and continuously over the character display, giving instantaneous feedback of the exact position of the input device.

Proportional Input on the MOD Keyboard

Wanting to provide for proportional input devices, and with the above considerations in mind, we have achieved a smoothly moving cursor on the video screen of the MOD Keyboard. The implementation was possible because of the VIC-20's capability for defining an optional character set. In effect, a cursor which can occupy any pixel coordinate location on the screen is created by redefining "on the fly" four characters which comprise the cursor shape plus the character, or parts of characters, over which the cursor happens to appear at any given instant.

A cursor "search" capability has also been developed in software. This means that the cursor will search for the nearest non-blank item on the screen. If the cursor remains within range of this item for an adjustable period of time, then the item will be highlighted by alternately blinking in and out of reverse video. The item may be a character, word, or phrase. Highlighting of the whole item makes it stand out clearly from all others on the video screen. The advantage of the search function is that the cursor does not need to be positioned so accurately, nor held constantly in an exact position, in order for an item to be selected from the screen. Selection can take place automatically after another adjustable time delay, or it can be activated by a separate switch (such as puffing lightly on a pneumatic tube built into the mouth transducer).

Now that we have developed a smoothly moving cursor with a search capability, we are able to utilize a variety of proportional input devices on the MOD Keyboard. The VIC-20's game input port will accept a light pen, an analog (potentiometer-type) joystick, or any device which simulates a pair of potentiometers (such as a graphics tablet). With any of these devices the disabled user will be able to rapidly position the cursor on the screen to the desired character, word, phrase, or computer command. These input devices can be controlled by various body parts: mouth, chin, cheek, head, hand, finger, or foot. Large range of motion or very small range of motion can be accommodated simply by choosing the appropriate input device.

The MOD Keyboard is programmed to provide even more adaptability to the individual user. With proportional input devices, any jitter or tremor caused by the user will also be added to the desired input signal. We have implemented simple software routines, however, which "damp out" or filter the jittery component from the input signal, allowing the cursor only to move smoothly from point to point on the screen. The amount of damping, and also the "gain" or sensitivity of the input transducer, are both user adjustable.

Advantages of Proportional Input

The most significant advantage of position-proportional input is, of course, the fact that the user can rapidly move the cursor to directly select any item displayed on the MOD Keyboard's screen. Proportional input on the MOD Keyboard also means greater adjustability to each individual user and ease of positioning the input transudcer separately from the display. These advantages are added to the MOD Keyboard's existing features of visibility of words and commands and user programmability of all screen display pages.

Now that we have proportional input and proportional display capabilities, a wide variety of possibilities are opened up for different scanning and selection techniques, including those ideas suggested by Gaddis (5). For example, using a self-centering potentiometer joystick, proportional scanning can be implemented, as compared to position-proportional control, described above.

There is also no reason why the smoothly moving cursor cannot be used for row/column scanning and for directed scanning with single or multiple input switches. In fact, once it has been tried, one wonders why it has taken so long to get out of the "horse and buggy" era, where our thinking was tied to the concept of a matrix board of LED's, and into the modern "high tech" era of truly utilizing video display capabilities. Considering the visual perception aspect, the smoothly moving cursor is much easier to follow than the jumping cursor employed previously. Users will be able to work with faster scanning speeds and with less of the former tension which had been caused by trying to stop the jumping cursor at exactly the right instant in time.

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EXPLORATION OF MINI-BUS ARCHITECTURE FOR COMMUNICATION AND CONTROL AIDS FOR SEVERELY HANDICAPPED INDIVIDUALS

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ABSTRACT - Prentke Romich Company was awarded a Small Business Innovation Research grant by the National Science Foundation to perform a feasibility study on a modular approach to communication and control air design. This paper reviews that research.

RÉSUMÉ - La Prentke Romich Company a reçu une bourse de recherche pour innovation (Small Business Innovation Research Grant) de la National Science Foundation afin de réaliser une étude de faisabilité relative à une conception modulaire des aides à la communication et à la commande. La présente communication examine cette recherche.

I. IDENTIFICATION OF THE PROBLEM

Technical advances in both processing and control technologies are providing rapid increases in capability and decreases in price for general mass market systems and devices. The cost for communication and control aids for handicapped individuals, however, is increasing. Two major causes of this are increase in costs for research and development, and the decreasing lifetime for individual aids due to technical advancements.

II. BACKGROUND

To date, all communication/control aids have been designed as special function, one-piece units. Although occasional use has been made of functional sub-assemblies, there has been no real modularity or interchangeability.

The objective of the completed Phase I research was to determine the feasibility of an entirely new approach to communication/control system design for severely handicapped persons. This new approach is based on the modular use of independent and compatible function units, connected by a single bus.

To accomplish this objective six steps were completed during the course of the Phase I study:

A. Identification of the population and their needs.
B. Definition of the functions that any proposed bus architecture or system must support.
C. Establishment of the general areas of criteria that would be used to evaluate a proposed architecture or system.
D. Identification of possible alternate architectures.
E. Evaluation of the alternate architectures and selection of one as a target solution.
F. Discussion of the feasibility of the target solution.

III. RESULTS

A. For the purpose of the needs assessment, we have divided the pertinent disabled population into three mutually exclusive categories:

1. Spinal cord injury with some arm impairment.
2. Motor-impaired ambulatory.
3. Motor-impaired non-ambulatory (excluding spinal cord injured).

Although the various physical constraints of the target population are not distinct and the needs are interrelated, seven pertinent areas of need have been identified. The needs addressed by the proposed communication/control system are identified as:

1. Conversation
2. Portable writing
3. Computer/information processing access
4. Environmental control
5. Mobility
6. Arbitrary device control panel access
7. Manipulation

B. The functions that address user needs are represented in the diagram. The mass market determines that some functions are presently best implemented as base (stationary computer) oriented functions. Therefore, all these functions can presently be regarded as the one function of interfacing with a stationary base computer. This does not mean that these functions can be ignored. Any suitable system must allow for these base functions to move onto the portable portion of the system as mass market trends make it feasible to do so.

The diagram illustrates the configuration of communication between the output functions and the portable/stationary controllers. The broken lines indicate those functions which presently favor data communication through the stationary computer. These functions may, however, in the future communicate directly with the portable main processor.

Any of the lines of communication could be implemented with a wireless link. The most favorable path for a wireless link would, of course be the path between the portable main processor and the stationary base computer.

The communication configuration as illustrated in the diagram was used as a base for identifying various possible alternate architectures that could provide the functions that have been identified.

C. With the goal of maximizing the benefit to the user, four main areas of criteria were identified:

1. The cost of the system
2. The useful lifetime of the system
3. The tailorability of the system
4. The skills required to properly specify, apply, install, and maintain the system.

D. A description of the identified alternate architectures is beyond the scope of this paper.

E. The evaluation of the alternate architectures and selection of a target solution were accomplished by applying the following criteria to each architecture. These criteria represent the previously defined areas:

1. The entry cost
2. The upgrade cost
3. The support and maintenance cost
4. The ease of enhancing functions
5. The ease of adding functions
6. The ease of tailoring the input
7. The ease of tailoring the output
8. The ease of tailoring the processing
9. The ease of implementation for manufacturers
10. The ability to use mass market commercial products

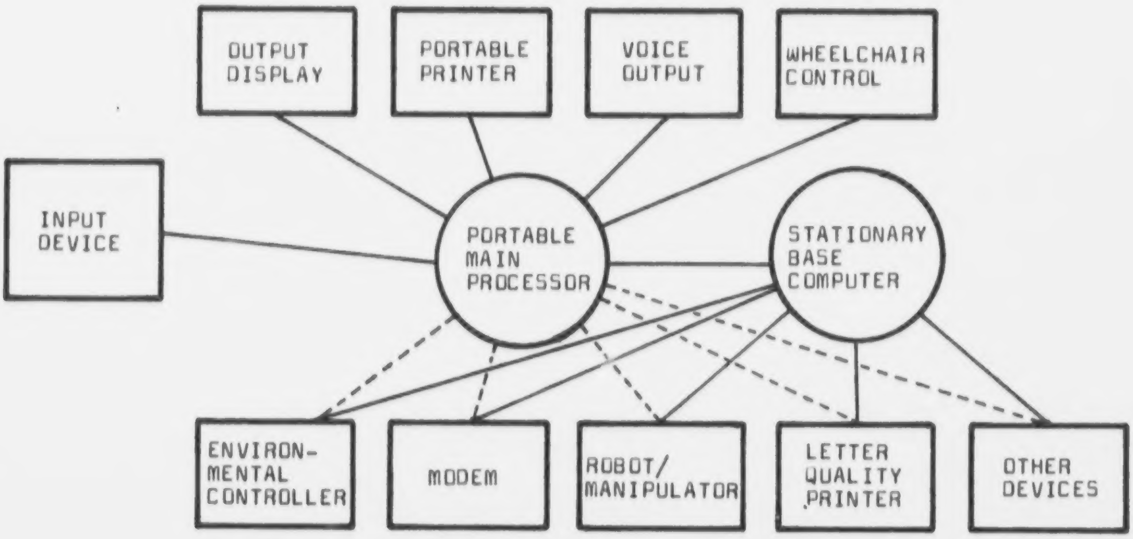
F. The technical feasibility of the target solution depends on further study on the demands that would be put on the bus. The Phase I study included a preliminary study of the technical feasibility.

IV. CONCLUSION

The Phase I study concluded that the proposed approach is feasible if further research indicates that a suitable bus can be found or created. This study included a preliminary investigation on presently existing buses to determine if any could perhaps be suitable for implementing this approach. It was found that more work is necessary to determine if any existing buses are suitable. At this time there is not enough known about what the demands would be on such an implementation of a bus. Therefore, it is not possible to positively determine the suitability of existing buses. A suitable bus for this implementation may be in existence now or may be in existence soon through the developments of other mass market industries which deal with portable equipment. Regardless of whether an existing/future commercial bus is adopted or a custom bus is designed, further work (that of determining the demands of the system) will be necessary if the approach is to be taken.

This Phase I research was funded by the National Science Foundation under the Small Business Innovation Research program. Prentke Romich Company has submitted a proposal for Phase II funding. Phase II is the principal research effort.

PORTABLE/STATIONARY SYSTEM



SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 4

SELECTION OF TECHNICAL AIDS/
CHOIX DES AIDES TECHNIQUES

ISSUES IN EVALUATION

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ABSTRACT - This paper will briefly discuss some special issues in the interdisciplinary framework or rehabilitation product evaluation. New, more flexible technologies mandate new procedures for evaluation of needs determination, design choice, clinical testing, as well as, psychosocial and socioeconomic issues.

RÉSUMÉ - Cette revue du cadre interdisciplinaire de l'évaluation de produits techniques se concentre sur quelques problèmes spéciaux. Les technologies actuelles plus flexibles demandent des procédures nouvelles relatives à l'évaluation des besoins, des choix techniques, de l'expérimentation en clinique ainsi que des problèmes psycho-sociaux et socio-économiques.

NEED

According to the Office of Technology Assessment (OTA), evaluation of new technologies "should be put into a larger perspective."[6] But the diverse needs of different technologies make a systematic and coherent evaluation methodology problematic.

> Evaluation is-- or should be-- an ongoing and integral part of the entire lifecycle...A coherent, and well-focused program of evaluation is necessary at all levels of technology diffusion and adoption. Such a program does not currently exist in the disability-related policy area-- and everyone seems to believe in the concept but few satisfactory schemes to improve the situation were suggested to OTA and few people or agencies appear to be taking aggressive steps to put the concept into practice. [7]

At the onset, there are a number of different models or frameworks that can be used to perform evaluation. The use of various frameworks or techniques can produce differential interpretation of results. For instance, the OTA points out that conclusions about cost effectiveness of programs or devices can shift from being in a net savings or net loss position depending on the methodological approaches and often the "eyes of the beholder".[5]

There are many issues that remain unaddressed by traditional evaluation schemes. Evaluation has not generally assessed how a new technology fits into the current cultural and political settings. In the case of economic evaluation research, the focus has generally been on cost containment and not on the costs in relation to health outcomes. As a consequence, many of these schemes are often inappropriate when used alone.

These problems are compounded by the fact that evaluation is in a dichotomous position. On the one hand, there is the concern that evaluation procedures may slow the diffusion process. On the other hand, without evaluation, there is the concern that products will be researched, designed and developed but will never be diffused to the end user for whom they were funded. Worse yet, they will reach the end user but may be inappropriate for their needs; and the compliance rate for using the product will decrease.

From a marketing perspective, manufacturers need to be informed about publicly funded research and development. But from a societal perspective, there is an overall ethical concern that public R&D funds be invested wisely and used effectively for the public good. For instance, these concerns have been raised by Jonathan King in Technology Review regarding recombinant DNA and technology transfer.

> A number of corporations involved in exploiting recombinant DNA technology have obtained patents on organisms and processes, even though all of the development work was publicly financed. The scientists involved simply disassociated themselves from public funding and entered into relations with private companies, thus appropriating public knowledge for private accumulation of wealth not generally available to academic scientists.
>
> Although some scientific/industrial spokespersons have called for the unfettered (and unregulated) "search for truth," the controversy over recombinant DNA technology is not about freedom of enquiry; it is about regulating those who want to rashly exploit for private gain the fruits of knowledge that should belong to all.[3]

Robotics and other advanced technologies can raise the same ethical concerns. Since many publicly funded agencies do not have basic-research-to-marketing strategies or guidelines, the private sector has traditionally assumed the task of technology transfer and diffusion. This interaction of the public and private sectors needs to be examined with new evaluative procedures. Evaluation can serve as the focal point to study this relationship.

THE EVALUATION SPECTRUM

Evaluation should be an important part of each phase of a product's life-span. That is, thoughtful human factors considerations should be initiated at the onset of the needs finding phase[4] and remain part of the product spectrum through the marketing of the end product. Because these devices being produced will impact on human lives, scientists and engineers have an ethical responsibiliy to produce the most appropriate technologies possible. Evaluation can serve as support to designers, developers and manufacturers of proposed devices. The evaluation process can serve as a filter for innovative ideas and help assure more appropriate end-products. Just as setting standards for wheelchairs is becoming an increasingly important issue to developers and policy-makers, as well as end-users, setting standards for evaluation is also becoming a critical issue.

For instance, research methodologies need to be synthesized and brought to bear on problems. For example, the array matrix technique used in the Cost Effectivenss Analysis (CEA) methodology, suggested by OTA, allows us to examine the cost effectiveness of evolving technologies more thoroughly. Using theoretical models, developed by social scientists, allows us to use established social theories to examine newly evolving technologies. Using the critical path analysis, drawn from engineering and statistics, we can begin to look at various facets or dimensions of technology's impact. Furthermore, we need to actively examine issues such as: the influence of reimbursement on the development and diffusion of devices [1], the identification and descriptors of socioeconomic and psychosocial factors. These assessment approaches need to be synthesized and their analytical value determined. Device technology, like medical technology in general, does not follow a linear or steady path. Biomedical science and engineering science contributes "only a portion of the knowledge and research that is needed to develop an idea or technology fully".[6]

NEED FOR A NEW EVALUTION MODEL

A new evaluation model is needed which will ask questions that have social as well as technical implications. For instance, what are the implications of the technology for the patient? What are the implications for the patient's family? What are the implications for society and what are the implications for the medical care system?[6] Technology and information transfer should be considered of primary importance in the evaluation process. A major goal of a new evaluation framework should be to provide concurrent information and feedback to designers, developers, manufacturers and academic course designers.

CONCLUSIONS

New technological capabilities mandate new

CONCLUSIONS

New technological capabilities mandate new evaluation procedures. In the rehabilitation community, this is especially important because the resources are so limited. With new technological advances that allow a more generalized and less specialized approach, evaluation must adopt a more generalized and less specialized focus.

Information transfer will have to be considered a critical part of evaluation since it is appropriate that these broad range concerns begin to be addressed by a network of persons concerned with, or involved in, evaluation procedures. The VA and other publicly funded research and service organizations, such as RESNA, are excellent candidates to consolidate and array the critical issues raised in evaluating and implementing state-of-the-art technology such as robotics.

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CONSIDERATIONS IN THE SELECTION OF CONTROLS FOR ASSISTIVE DEVICES

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ABSTRACT - Assessment for appropriate control systems and assistive devices has been recognized to be of great importance in the delivery of service to physically handicapped persons. This paper will discuss some of the factors which must be considered in such assessments.

RÉSUMÉ - Il ne fait plus aucun doute que l'évaluation des systèmes de commande et des dispositifs d'aide appropriés est de la plus haute importance dans la prestation des services destinés aux handicapés. La présente communication analyse certain des facteurs à considérer lors d'une évaluation de ce genre.

INTRODUCTION

Today's technology provides a great variety of assistive devices and control systems for applications in the rehabilitation field including communication and mobility. Efforts have recently been made to quantify the performance of the user with different control systems(1),(2). Work has also been completed at OCCC in the development of a systematic assessment of individuals for single-input controls(3). This protocol promotes a clinical evaluation based on four key factors which have been termed MSIP - M ovement, S ite, I nterface, and P osition. Three computer-based (APPLE II) tasks - Response, Autoscan, and Hold/Release have been developed and used to objectify the evaluation of performance.

The above tools were developed to facilitate the selection of a control system. However, there are many factors that must be considered and defined before using these objective tools.

ASSESSMENT ENVIRONMENT

Key components to the assessment environment must be initially addressed. First, an equal emphasis on clinical and computer-based assessments is necessary. While microprocessors have become valuable tools to quantify in an objective manner those behaviours which are usually difficult to calibrate, these new measures are essentially an adjunct to the clinical assessment. A comprehensive assessment of an individual can be best achieved through a concerted effort by all the specialists involved. The interrelationship of the function of devices relative to the control system is very important in determining the optimal system for the individual.

Assessment of a client requires the clinician to have a good knowledge of various assistive devices, control systems, and how these components work together. This knowledge will enable the clinician to analyze the skills required for the specific functions and appropriately assess the client with these skills in mind.

It must be realized that following the initial assessment, clients, particularly the young and severely physically handicapped, will require additional motor training with the control system as well as training in the fluent use of the assistive device. These skills should be re-evaluated periodically to ensure that the systems meet the client's needs and reflect the individual's progress or regression.

METHODS OF CONTROL

Direct Selection : The availability of a wide range of aids and controls can present a problem to the clinician in deciding where to start the assessment. Direct selection methods such as activation of a keyboard (4) are relatively easy to learn and are generally the most convenient and the least expensive to set up.

Direct selection to control a device is not restricted to control through the hands. The use of head control for headsticks, light beams, and mouth sticks is easily implemented with commercially available technology. Even in the case of poor upper limb function, it is profitable to investigate methods of stabilization which will provide the user with increased control(5).

Indirect Selection : When the initial assessment indicates that a client cannot directly access a device, indirect selection systems using single and multiple switches must be investigated. In some cases a client may in fact have the ability to directly access a device, but this may be so laboured, that an indirect selection system may be warranted to reduce fatigue and increase efficiency. A recent study (3) has emphasized the importance of the preliminary assessment and identification of efficient and reliable movements prior to trials involving various interfaces and positioning of the interfaces.

In selecting interfaces many factors must be considered. The sensitivity (amount of force required for activation) of the interface must match closely the client's strength as well as the nature of his movement. Feedback (auditory, tactile, proprioceptive) provided by the interface is especially important for younger clients, those with difficulties relating cause-and-effect, and those with proprioceptive problems. An interface must be highly reliable and durable to prevent any undue frustration for the client. Ease of repeated installation of the interface will have great bearing on how often it will be used. Interface characteristics such as comfort , cosmesis , and cost may also influence the final decision.

Frequently an identified efficient movement may also be one that the client uses for another purpose. If such movement is the client's most efficient control method but limits other activities such as observation of events in the classroom, then it must be weighed against the final effectiveness the client gains. A decision may be to use that control system only in a specific environment, such as a work-station.

GENERAL-PURPOSE OR DEDICATED CONTROL SYSTEMS ?

It has often been suggested that a client should use the same interface for communication and/or microcomputer control as used for mobility. Mobility interfaces are often referenced in this context due to their relatively long history of availability as compared with that of microprocessor technology for communication and other functions. There are two main advantages of using one interface for several purposes. First, costs for a connection from the mobility interface to other aids could be minimal compared to the cost of a new interface. Secondly, the individual would be familiar with manipulating the interface.

If a mobility control system has been assessed to be appropriate for other activities, ideally it must be guaranteed that it will work reliably with other aids and that the mobility interface can be positioned appropriately on another wheelchair when the electric wheelchair requires repairs.

Problems may arise when other devices require different ways to control the interface. Such problems were encountered in our previous research (3) in which 24 severely physically handicapped subjects were assessed for single-input controls for the computer. In 10 cases the clients' mobility interfaces were evaluated as possible controls for the computer. In another 5 cases the subjects' mobility controls were not used in the assessment because their performance on the mobility controls was much inferior to their performance with other control systems.

Fifteen of the 24 subjects could utilize a scanning strategy with a cursor speed of one second or less. However, only one subject used the mobility control with this level of efficiency; generally the subjects' responses with their mobility controls were much slower. Other control systems were used with greater effectiveness. Also, use of mobility controls often encouraged sitting postures that were not conducive to watching the computer monitor.

The main reason for this difference in functional performance is the fact that different activities require different skills. To fully understand this problem one must examine the different ways that mobility aids, communication devices, and microcomputers work and not focus solely on how the interface works.

The most common way to drive a wheelchair is by maintained activation of an interface, and release of that interface to stop. This system requires active but not necessarily fine control of the interface by the user. For example, a person can maneuvre their electric wheelchair with a discontinuous control as well as a smooth continuous control.

The main difference in using this maintain-activation-release for operating communication devices or computers where selectable items are placed in closer proximity to each other is that finer control is required. The ability to "stop on a dime" is much more crucial in these devices than in driving an electric wheelchair. Communication aids and computers usually require several input commands before a message is composed; poor control of the interface may make operation of the device very difficult and frustrating, perhaps impossible. Good control of an interface for a communication aid may warrant evaluation of this method of control for other activities such as mobility.

SUMMARY

The impact that a functional activity has on the selection of the control system warrants evaluation of the specific activity-control system combination rather than a blind acceptance of the notion of one control system for all activities. It is also important to develop measures which will allow comparison of a client's efficiency using direct access and single and multiple input control systems with a specific activity.

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TECHNOLOGY AND INDEPENDENT LIVING - A NATURAL?

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ABSTRACT - This article attempts to enlarge the perspectives of the developers and providers of technology to encompass aspects of independent living for people with disabilities. It cites some of the conditions that must exist to properly integrate disabled individuals into the process of developing and applying new technologies. The article also advocates a partnership between disabled individuals involved in the independent living movement and the developers such as RESNA.

RÉSUMÉ - La présente communication tente d'élargir la perspective de ceux qui mettent au point et fournissent la technologie afin qu'ils tiennent compte de l'autonomie des handicapés. On énumère certaines des conditions qui doivent être réunies pour bien intégrer les handicapés dans le processus de mise au point et d'application des technologies nouvelles. On préconise également une association entre les handicapés qui prennent une part active dans le mouvement "Vie autonome" et les responsables du développement technologique tel le RESNA.

The purpose of the development and application of technology is problem solving. Unless there is a stated problem, there is no need to develop a technology. If a technology does not solve the stated problem, it is worthless. If it does solve the problem, a technology proves to be quite valuable. A most important consideration in developing and applying new technology is that while solving a stated problem other problems should not be created. Disability when imposed in its varying forms on individuals creates a myriad of problems in need of solutions. Thus, it appears that there is a natural relationship, based on need between people with disabilities and those people who develop and apply technology. For the most part the development and application of technologies related to people with disabilities has centered on the restoration of a problem with physical function. This is a very narrow focus and lends itself to both limiting the ability of technology to solve problems for people with disabilities and creating additional problems for people with disabilities when the technology is applied. Perhaps a different perspective, that of considering the independent living aspect of the development and application of technology would be more appropriate. In order to have this perspective some of the basic tenets of independent living as developed by people with disabilities, should be considered. Among these tenets are: (1) people with disabilities are people, (2) people with disabilities have many of the same needs and desires as people without disabilities, (3) among the needs of disabled people is the need to remain in control of their own lives, (4) in order to maintain control of one's own life one must make informed decisions, (5) people with disabilities have the ability to make informed decisions, (6) people with disabilities desire to carryout their everyday activities with as little dependence on others as possible, (7) people with disabilities can individually and collectively do much to solve many of the problems they face themselves, (9) many of the problems related to having a disability are the result of the environment rather than inherent to the individual, (10) with appropriate supportive services, people with disabilities can lead relatively independent lives, (11) the extent and manner in which independence is achieved will differ with each individual with a disability, (12) people with disabilities are entitled to choose to accept risk as a part of living independently, and (13) for disabled people to live independently they must become actively involved in those activities which effect them and assume the locus of control.

The above tenets of independent living apply not only to the disabled but to the non-disabled who choose to live their own lives in an independent fashion. These tenets have been identified during the development of the independent living movement as being critical to disabled individuals and their ability to achieve an independent life style. Many of the problems experienced by people with disabilities do not stem so much from a loss of physical function as from violations or lack of recognition of the above tenets in the way in which the disabled person interacts with the environment and the people in it.

A major principle of rehabilitation engineering is that adaptive aids should be simple, functional, and reliable, and generally economical. It is not uncommon to develop such a product and still not have the product properly utilized by a person with a disability. Could this be due to the fact that in the development and application of such a product, the considerations of independent living were not made? Irving Zola, co-author of the book, *Independent Living for Physically Disabled People*, cites that, "Rehabilitation personnel must change their model of service so that it focuses less on doing something *to* someone and more on planning and creating services *with* someone." He goes on further to say that, "Unless the rehabilitation world frees itself from some of its culture bound and time limited standards and philosophy, we may one day find ourselves in the position of Walt Kelly's Pogo who once exclaimed: 'We have met the enemy and he is us.'"

If the development and application of

technology is geared toward achieving independent living for disabled individuals much more than the simple achievement of restored physical function can be achieved. The full participation of disabled individuals in their community and those activities which surround them can be achieved. In order for this to occur those persons responsible for the development and application of technology must take a broader look at the way disability poses problems for individuals. People with disabilities must individually and collectively be involved in the development and application of technology to the problems created by disability. Active efforts must be made to inform disabled individuals of the technology which does exist and which can be developedin the near future. As a prerequisite to the development and application of technology, disabled individuals must be involved in the identification of problems associated with disability. In addition to being made aware of the existence of technologies disabled individuals must be able to gain access to demonstrations for personal test applications of these technologies in meeting their particular needs without substantial financial investment. Some assurance should be available to disabled individuals that if technologies are developed or applied in meeting their disability related problem that the cost of such technologies will not be out of reach. Finally, there should be active efforts to involve disabled individuals in those occupations responsible for the development and application of technologies to problems related to disability.

At the Sixth Annual Conference of Rehabilitation Engineering Society of North America it was gratifying to see the number of disabled individuals participating in the conference. There was a substantial effort on the part of RESNA to involve disabled consumers in the activities of the conference. As a result, the disabled individuals gained insight into existing technologies as well as developing technologies. It was quite apparent that many of the participants in the conference without disabilities were able to gain substantial insight into the problems of disabilities from the input given by the consumers. As a particpant representing the Easter Seal Center for Independent Living in Memphis, Tennessee I was impressed by the active participation of disabled participants in the development and application of technologies related to disabilities. As an example one of the most impressive personal contacts made at the conference was that made with a cerebral palsy quadraplegic who was trained as an engineer and who developed and produced an electric wheelchair, specifically for his needs, which appears to have applications of a broader perspective to many other wheelchair users with similar needs. It therefore appears that, through the efforts of RESNA, a beginning has been made toward integrating technology and independent living. Perhaps this relationship can be fostered in other ways such as introducing available technologies through centers for independent living as is done in Australia or as indicated in the publication, "Technology and Handicapped People" developed by the Congressional Office of Technology Assessment actively involve the Congress in seeking solutions to breaking down the financial barriers to the use and availability of technologies.

It appears that there is a natural partnership between independent living and technology which can be achieved through partnerships established between the independent living movement and the developers and providers of technology such as the members of RESNA.

In an article titled, "The Need for Full Integration of Disabled Persons in Their Society" authored by Bruce M. Curtis and published in "International Aspects of Rehabilitation" David Werner makes the following comment, "Disabled people and especially disabled service providers are oftened treated like children or amateurs by their more highly educated trainers and supervisors. This is a great mistake. People with little formal education often have their special insight, skills, and powers of observation which intellectuals have never acquired and therefore fail to perceive. If this innate knowledge and skill is appreciated, and integrated into the disabled service process, this will not only make it more truly community oriented and viable, but will help preserve the individual strengths and dignity of the service provider and disabled people. I cannot emphasis enough how important it is that professional service planners, instructors, supervisors and trainers be tuned into the capabilities and special strengths of the people they work with."

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THE UTILIZATION OF ASSISTIVE DEVICES BY CHILDREN

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ABSTRACT - Assistive Devices are frequently prescribed for children. There is however little information about how frequently devices are used. This study examines the use of devices in over 500 families in Ontario prescribed devices and paid for through the Assistive Device Program.

RÉSUMÉ - Les prothèses et autres dispositifs sont souvent prescrit aux enfants, il y a cependant peu d'information à savoir si les prothèses sont souvent utilisées. Cette étude cherche à contrôler la fréquence de l'utilisation des prothèses et autres dispositifs qui leurs sont prescrits et payer par l'intermise du programme d'aide à l'achat de prothèses et autres dispositifs.

The use of assistive devices has expanded rapidly during the past decade and provincial governments in Canada and both national and state governments in other jurisdictions have developed programs to fund the cost of these devices and/or to directly supply such devices. In addition third party payment by private health insurance companies has become widespread.

There has however been very little research on the utilization of devices and no reported research on the utilization of devices supplied through a province-wide program.

In order to provide information on the utilization of assistive devices in the first year of operation of a province-wide program that provided 75% of the cost of selected assistive devices, a survey was conducted on a 10% sample of users. The survey was a combined telephone-mail effort. Letters and a questionnaire were sent to the parent or guardian of 747 users of the Assistive Devices Program. We were unable to contact 150 families by phone and complete information was obtained from 502 families. No significant differences could be detected between responders and non-responders. Responders had received a variety of aids including: Hearing aids (22%); wheel chairs (10%); mobility aids (6%); braces and splints (28%); seating and positioning devices (8%); pressure modification equipment (2%); prostheses (6%); genito-urinary supplies (10%); respiratory equipment (8%).

Eighty three percent of the assistive devices were still in use at the time of the survey. RAtes of utilization varied across the types of devices and the type of question used to ascertain utilization.

The activities that children could do with the devices that could not be done without the device included activities classified as: functional positioning; corrective positioning; communication; continence; mobility; social acceptability; recreation; life support; and enegy saving.

The durability, comfort and appearance of the aid and their importance to the family was generally very high.

Further details of the results of the survey and suggestions for future research will be presented.

SIX CRITICAL FACTORS IN THE PRESCRIPTION OF TECHNICAL AIDS

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ABSTRACT - This paper outlines the results of a 52 point evaluation on 108 device loans over 22 months. Critical to a successful client/device match are effects on the user, effects on the others in the environment and total hours of use.

RÉSUMÉ - Cette communication décrit les résultats d'une évaluation selon 52 critères de 108 dispositifs prêtés sur une période de 22 mois. Les effets sur l'usager, les effets sur les personnes voisines et le nombre d'heures d'utilisation sont critiques pour une bonne harmonie entre le client et l'appareil.

The Technical Resource Centre provides 5 services including information searches, consultation, education, client assessment, and equipment loan with respect to technical aids.

A fifty-two point questionnaire was developed to evaluate the success of each device solution. The first seven points describe the device loaned, the client's medical diagnosis, and age, cognitive and physical skills, and the number of hours use per week. The next thirty-eight points asked the evaluator, usually a therapist, to respond on a scale of 1 to 5 concerning the difficulty and appropriateness of the device solution. These questions covered the topics of effect on the user, effect on others in the environment, problems with training and operation, design of the aid, durability and reliability and the decision to purchase the device.

Results

Evaluations were completed on one hundred and eight device loans over twenty-two months. They were grouped into four categories: toys (n=20) mobility (n=10), aids to daily living (n=24) and communication (n=54). The clients served were diagnosed as Cerebral Palsied 48%, Neuromuscular Disease 14%, Traumatic Head or Spinal Cord Injury 12%. Although their ages ranged from 1 to 75 years there was clustering in the 1 to 6 bracket (26%) and 18 to 25 years (20%).

The majority were physically disabled but with normal cognitive skills. Needs were priorized as follows: communication, toys and switches, eating aids, call signals, page turners and mobility devices. Those with low or unknown cognitive skills were matched with toys and simple communication devices as a first step to development and an introduction to technical aids. Good seating and mobility are known to affect cognitive development. TRC encouraged referring agencies to begin work in this area prior to device/client evaluations.

Even after a four week evaluation period, evaluators rejected or were unsure of the appropriateness of the proposed device solution (74%). Clearly "one shot" assessments and prescriptions are to be avoided. Most rejections were due to the over-estimation by parents and therapists of the users skills, and under-estimation of the demands of the device.

Six Factors in the Decision Process

If the aids are put into two groups (those accepted and those rejected) several significant factors emerge.

Aids to communication, daily living and toys were accepted based most strongly on user reactions, followed by listener or "other person" reactions, and the design and reliability of the device. However, mobility aids were not accepted or rejected dependent upon others' reactions, but only on user reaction and device design.

As expected, there is a strong link between effects on the user and effects on others' in the environment suggesting that although this is a "user/device" match its changes on the environment must not be ignored.

Aids to daily living were sometimes accepted if their effect on others' was noticeable; but frustration felt by the user always led to rejection.

Communication aids were usually accepted if they had a positive affect on the listener; but were rejected if there was a negative affect on the user. The reverse situation was not true.

Daily Use?

Aids to communication and daily living were more likely to be rejected if used less than one hour per day, but accepted if used two to four hours per day, seven days a week! Toys were rejected if used only fifteen minutes a day, but accepted if used forty minutes or more per day. Compare these minimum figures with a typical therapy regime of only two or three times weekly for half an hour.

Who Decides?

Possibly because so many clients were non-verbal, the decision to accept or reject a device was left to others' in the environment. Certainly with toys this was the case: the child's motivation came second to the teacher's or parent's reactions. Only when the user experienced a negative reaction such as frustration, loss of independence, socialization, motivation etc. was the aid rejected. We must be careful to consider whose needs we are meeting, and who is to gain independence through the device solution.

Communication Aids

Although some aids were frequently prescribed such as the Sharp memowriter or Handivoice, after a month of evaluation their rank ordering was noticeably changed. Handivoice, the VIP communicator and scanning aids all tended to drop suggesting they are more demanding than at first expected.

Aids requiring higher cognitive skills and used more by adults included the Sharp memowriter, Handivoice 110 and 120, VOCAID, ZYGO 16 and 100 and the VIP communicator.

Aids requiring moderate cognitive skills and used by children or adults included the Canon Communicator, the Viewpoint Optical Indicator, Bliss Scanners, Message Selector, Speak'n Spell, Proscan, Form-A-Phrase.

Aids requiring low cognitive skills and used by young children included the Viewpoint Optical Indicator, Proscan, E-tran Frame, Si-Com Picture Board, and Com-tube (Roll-O-Bliss).

Appendix I

Evaluation questions were compiled from the following sources:

1. Chedoke/McMaster Device Evaluation Hamilton.
2. Assistive Device Centre Evaluations, Sacramento California.
3. Project Threshold: A model system for delivery of Rehabilitation Engineering Services; Rancho Los Amigos Rehabilitation Engineering Center, University of Southern California, 1979.
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8. Non-Vocal Communication Workshop Materials, G. Vanderheiden, 1981.
9. Environmental Control Systems and Vocational Aids for Persons With High Level Quadriplegia. Rehabilitation Monograph No. 55, Institute of Rehabilitation Medicine, New York University Medical Centre, 1979.

Appendix II Aids Evaluated

001 Able table
002 Bliss scanner
003 BSR-X-10
004 Call signal
005 Canon communicator
006 Computers
007 Computer peripherals
008 Dufco matrix communicator
009 Eating aids
010 Electric cart
011 Enco IV
012 E-tran frame
013 Form-a-phrase
014 Handivoice
015 Light beam indicator
016 Message selector
017 Mouthsticks
018 Nolan bathchair
019 Optical stripprinter
020 Qed page turner
021 Rotary scanner
022 Row car
023 Roll-o-bliss
024 Roto-table
025 Saltus reader
026 Sharp memowriter
027 Si-com
028 Switches
029 Telephone adaptations
030 T.V. controller
031 T.V. memory
032 Timer/counter
033 Toys
034 Ultra IV
035 VIC
036 VIP communicator
037 Vocaid
038 Wheelchair - Amigo
039 Wheelchair - Child - 34
040 Wheelchair - Adult - 3p
041 Wheelchair - LEM
042 Writing aids
043 Zygo scanner
044 Other

TECHNICAL AIDS FOR THE COGNITIVELY HANDICAPPED

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ABSTRACT - This study of products to help people with cognitive limitations began by reviewing existing products. Medical specialists and others concerned with the issues were interviewed. A large-scale survey of retarded, stroke-victimized, and other cognitively handicapped individuals were surveyed using a mailback technique. These approaches defined the areas in which new product development would be most worthwhile.

RÉSUMÉ - The second phase of the project consisted of the preliminary development of products in the following areas: memory aids, safety help, communications, physical aids, map aids for transportation, teaching/learning tools, and "networking" or information access through videotex.

There have been great strides in recent years in the development of aids, products and adaptations for helping people with physical disabilities. They range from simple adaptations, like lowering public telephones, to complex and highly technical devices, like myoelectric limbs.

Cognitively handicapped people can also benefit from the development of technical aids. They encounter many problems in daily living, transportation, education, employment, and recreation. Some of these problems could be eased by new products or by adaptations.

Cognitive disabilities can result from retardation or other developmental delays, brain damage, stroke, or problems associated with getting older. The needs of mentally disabled people vary with the degree of their disability, their age, and many other factors.

Behavioural Team has used a variety of research methods to advance the design and development of technical aids. The focus was on products fostering independence and gainful employment. The goals of the study were to:

- assess the "state of the art" in technical aids for the mentally disabled,
- determine the range and priority of unmet needs that could possibly be helped by new aids or products, and
- examine the feasibility of different suggested developments.

A review of the available products literature indicates that this field is at an early stage. Companies specializing in rehabilitation of the physically disabled have some products that are also useful to the mentally handicapped. Other aids have been developed by people working with specific groups of cognitively disabled persons. However, there were no comprehensive summaries of aids for mentally disabled people. Even computer databases dealing with technical aids for the disabled did not have an indication of products that would be useful for someone with a cognitive impairment.

Research literature describes many of the cognitive problems of mentally disabled people. Some specialized aids and adaptations are also mentioned here, although many of them aren't commercially available.

By pursuing many different approaches, we compiled a list of presently available products and aids for the cognitively disabled. The difficulties encountered in compiling this list highlight another problem faced by mentally handicapped persons. They would have extreme difficulty finding out about available technical aids!

The greatest past development seems to have been in communications. There are many different communication products on the market. They range from simple pictorial aids to technically sophisticated voice synthesis or reading equipment. Communication is a basic problem for many cognitively disabled people, especially survivors of stroke or brain damage. Many mentally handicapped persons have communication problems that could benefit from further product development.

Mentally handicapped people can also benefit from specialized learning materials, memory aids, self-help devices, special furniture, protective wear, and physical aids. Some devices and adaptations have been developed especially for the mentally handicapped.

However, information about all of these products is not always readily available to cognitively handicapped people or to those professionals, volunteers and family members who help them.

The next phase of the study involved interviews and surveys of mentally disabled people and associated volunteers, professionals and family members. The information gained from these persons indicates some of the unmet needs of mentally handicapped people.

Most respondents were very open and informative about needs and problems. Some felt that development of human resources was more important than new products. However, many product suggestions arose in this work. These surveys and interviews also confirm that people aren't aware of the aids that are available.

Cognitively handicapped people encounter major problems in employment, transportation, education and several other areas. They require assistance for many activities. They universally expressed a need for more public education to help people understand and accept mental disabilities.

The last phase of the study involved assessing the feasibility of developing different sorts of new aids and products to help solve remaining problems. We interviewed designers, manufacturers and rehabilitation professionals to develop suggestions and guidelines for new products. These suggestions are outlined in the report and in several separate sections on specific types of aids.

Some of the same guidelines are appropriate for any good design. Signs and instructions need to be simple, clear, and unambiguous whether the user has a mental handicap or not. Products should be durable enough to survive misuse as well as use. These considerations are especially important in designing for mentally disabled users.

Some areas where new products or aids could assist mentally handicapped persons are transportation, learning, memory, safety, communication, information access and physical activities.

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LA TECHNOLOGIE MODERNE ET LES PERSONNES À MOYENS PHYSIQUES RESTREINTS: LE POINT DE VUE D'UN CONSOMMATEUR

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RÉSUMÉ - Cette communication exprime l'opinion d'un consommateur impliqué dans le milieu de la réadaptation, sur les secteurs prioritaires de développement de la technologie moderne. Celle-ci doit jouer un rôle dans la prévention des déficiences, dans la réadaptation et le maintien dans le milieu des personnes handicapées. Elle doit être simple, accessible et contrôlée par les consommateurs.

ABSTRACT - This paper presents a consumers point of view on the future directions of rehabilitation engineering. Consumer involvement in setting research priorities will be discussed, as well as the role of technology both in the prevention of disability and in maintaining independence.

Tout le monde sait que la technologie a fait des bonds prodigieux au cours des dix dernières années. Les applications de la technologie de l'espace et l'avènement du micro-ordinateur ont ouvert des horizons inespérés. Les prochaines années sont donc fort prometteuses en principe.

Il est cependant assez récent que l'on tente d'une façon plus systématique de mettre cette technologie au service des personnes ayant une déficience physique quelconque. Bien que l'on ait déjà réalisé des choses importantes, il est arrivé souvent que l'on mettent au point des techniques ou appareils dont l'utilité est douteuse, dont les coûts sont très élevés et accessibles à une petite minorité.

Il s'avère donc d'une importance capitale que les développements des prochaines années dans ce domaine correspondent aux besoins prioritaires des personnes directement impliquées. Je tenterai dans ce bref article d'indiquer les principaux domaines où cette technologie doit s'appliquer et quelles doivent être les principales caractéristiques de ces développements. Ce sont d'humbles opinions personnelles basées sur mon expérience de consommateur et celle de professionnel impliqué dans l'intégration des personnes handicapées.

La prévention, la réadaptation et le maintien dans le milieu

Il importe d'abord de définir clairement les différents domaines d'intervention possibles et les priorités pour chacun.

Il y a d'abord tout le secteur de la prévention des déficiences et des incapacités qui devrait être tout à fait prioritaire. En effet, il est et il restera toujours innacceptable en soi de vivre avec des diminutions physiques limitantes. Plusieurs s'en accomode avec le temps, mais personne ne les accepte vraiment. Il faut donc poursuivre une lutte acharnée pour éviter au maximum l'apparition des déficiences et des incapacités.

La technologie peut servir au niveau de la prévention primaire en ce sens qu'elle peut aider à rendre notre environnement le plus innoffensif possible. Le contrôle des différents types de polution entre dans cette catégorie. Il y a ensuite et surtout la prévention tertiaire qui consiste à limiter les conséquences de déficiences qui sont déjà apparues. Le vieillissement de la population s'accompagne par exemple de problèmes circulatoires causant des déficiences comme l'amputation et les accidents cérébro-vasculaire. C'est maintenant la principale cause d'handicap. Toute découverte biotechnologique permettant de contrôler ce phénomène serait une véritable révolution.

Pour ce qui est de la réadaptation proprement dite, on peut la définir comme un "processus global,personnalisé, coordonné et limité dans le temps des différents moyens mis en oeuvre pour permettre à la personne handicapée de développer ses capacités physiques, psychologiques et mentales et ses possibilités d'autonomie sociale."

La technologie peut jouer un rôle important particulièrement au niveau des différents traitements (physiothérapie, ergothérapie, orthophonie, etc.) associés à la réadaptation fonctionnelle. Il s'est développé toute une quincaillerie à ce niveau dans les dernières années qui n'a malheureusement pas toujours de base scientifique. Il apparait prioritaire d'évaluer de façon scientifique et contrôlée les résultats concrets de ces différents appareils et techniques d'intervention. Bien qu'il soit important de rester ouverts au développement d'approches nouvelles à ce niveau, il faut éviter qu'elles ne soient appliquées sur une large échelle avant qu'elles n'aient fait leurs preuves.

Après que les personnes handicapées aient réalisé un processus de réadaptation maximal, elles doivent tenter par la suite de réussir à vivre dans leur milieu de vie naturel ou dans un milieu qui s'en approche le plus possible. Cet objectif primordial est conditionné par une série de facteurs de l'environnement et de services pouvant être offerts dans une société.

Les promoteurs du principal courant de pensée moderne vis-à-vis les personnes handicapées depuis 10 ans an Amérique, le mouvement de vie autonome, considèrent ces facteurs comme les plus cruciaux pour leur intégration. Pour les tenants de cette approche, cela est même plus important que la réadaptation.

En accord avec ce paradigme social mettant l'accent sur l'environnement, je considère que l'on doit consacrer la plus grande part de nos énergies futures avec la technologie pour l'amélioration de quelques-uns de ces facteurs. Je pense plus particulièrement aux quatres facteurs suivant:

- L'accès architectural au logement et aux édifices publics.
- L'ensemble des moyens permettant la mobilité.
- L'ensemble des aides techniques favorisant l'adaptation du milieu physique.
- L'ergonomie ou l'adaptation des postes de travail.

Une technologie simple, accessible à tous et contrôlée par les consommateurs

Dans ce domaine comme dans d'autres, plusieurs chercheurs sont tentés de mettre au point l'appareil où la technique la plus sophistiquée et la plus nouvelle que l'on puisse imaginer. Chacun a l'ambition de faire avancer la science d'un pas, et en même temps, sa carrière.

C'est ainsi qu'il est possible de trouver aujourd'hui des appareils très complexes et très coûteux, mais produits à quelques exemplaires seulement. Pendant ce temps, je connais encore des centaines de personnes qui se promènent dans les rues avec des fauteuils roulant motorisés qui ne sont pas munis de freins autres que manuels. Ces véhicules sont carrément non sécuritaires. De plus, la quasi totalité de ces fauteuils sont encore munis de sièges constitués de deux toiles rigides perpendiculaires. On ne retrouve aucune préoccupation du comfort pour des personnes assises des journées entières.

Un autre exemple frappant est l'absence encore aujourd'hui de moyens simples et peu coûteux de franchir les barrières architecturales qui représentent pourtant un problème évident.

J'insiste donc sur la nécessité que les chercheurs mettent dorénavant l'accent sur la réponse aux besoins les plus essentiels et les plus fréquents. Il faut aussi utiliser au maximum les techniques où les appareils existants et voir à les adapter plutôt que d'en créer de toute pièce.

Il est en effet très important de tenir compte du fait que le marché sera toujours assez limité dans ce domaine. À cause de ce fait, la création de toute nouveauté amène des coûts de fabrication très élevés. La conséquence de cela est l'accessibilité restreinte de ces appareils.

L'accessibilité des applications de la technologie est en effet une question fondamentale. Il est difficilement acceptable socialement que des appareils remplacant des fonctions essentielles de la vie ne puissent être acquis que par des personnes ayant des sommes considérables à y consacrer. Il existe des programmes qui sont nettement discriminatoires comme par exemple le programme Québécois de financement des aides visuelles et auditives qui ne s'applique que pour les personnes de moins de 35 ans. Il apparait élémentaire que le coût des aides techniques répondant à des besoins essentiels soit couvert par des sources publiques pour toutes les personnes qui en ont besoin. Celà répond au principe de plus en plus reconnu que les personnes n'ont pas à subir, en plus des autres inconvénients, les conséquences économiques d'une déficience physique.

Le moyen sûrement le plus efficace pour assurer cette accessibilité au cours des années à venir réside dans l'implication des personnes handicapées pour le contrôle de ces développements.

Les représentants des personnes ayant des limitations physiques doivent prendre l'initiative de s'associer aux principaux organismes de recherche afin d'y jouer un rôle important. Elle pourront ainsi s'assurer que les développements technologiques en cours répondent d'abord aux intérêts des consommateurs et qu'ils collent aux besoins les plus essentiels. Elles pourront de plus voir à ce que les appareils les plus importants soient financés par des fonds publics en faisant les démarches et les pressions politiques nécessaires. Il est évidemment souhaitable que cette participation soit acceptée et encouragée par les chercheurs.

Malgré les réserves émises dans cet article, il n'en demeure pas moins que la technologie moderne représente un espoir majeur de mieux conserver et restaurer l'autonomie physique et sociale de la personne humaine.

LA TECHNOLOGIE, SES POSSIBILITÉS ET LIMITES FACE À L'INTÉGRATION SOCIALE DES PERSONNES HANDICAPÉES

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RÉSUMÉ - Les auteurs, à partir d'expériences d'intégration vécues dans la communauté par 450 personnes lourdement handicapées, font l'analyse des possibilités de la technologie dans ce domaine. Il y sera question de mobilité, des aides à l'alimentation, des contrôles d'environnement, des aides à la communication et de l'accessibilité de ces diverses technologies mises au service des personnes handicapées.

ABSTRACT - On the basis of the experiences of 450 severely handicapped persons who were integrated into the community, the authors analyze the possibilities for technological applications in this field. They focus on mobility, eating aids, environmental controls, aids to communication, and the accessibility of the various technologies available to the handicapped.

La province de Québec a vécu un vaste mouvement de désinstitutionnalisation et de normalisation des personnes handicapées, depuis 1975. Sous l'influence des mouvements de promotion des droits des personnes handicapées, une vaste réforme des législations sociales a pris forme, de même que des modifications importantes dans le réseau de distribution des services de santé et des services sociaux.

Dans ce contexte, le Centre de Réadaptation François-Charon a mis sur pied différents programmes sociaux pour les clientèles handicapées de naissance et celles réadaptées au plan physique, mais nécessitant un support au plan psycho-social. C'est ainsi, que par la mise sur pied de différentes ressources alternatives (foyers de groupe, maisons de transition, ilôts résidentiels, etc.) nous avons eu à intégrer socialement et à maintenir à domicile tout près de 450 personnes très lourdement handicapées au plan physique.

Comme la grande majorité de ces personnes avait un besoin constant d'aide au plan de leurs besoins primaires (mobilité, transfert, alimentation, communication), nous avons du faire appel aux technologies disponibles en réadaptation et à celles déjà accessibles pour le consommateur moyen.

Par l'expérimentation de ces aides techniques, nous avons vécu à la fois des échecs et des succès. C'est ce dont il sera question dans la présente communication, ainsi que des différents facteurs pouvant permettre l'adaptation des nouvelles technologies aux besoins des personnes handicapées.

Au niveau mobilité, bien que le Québec soit privilégié par un programme de gratuité des fauteuils roulants, nous nous sommes rendus compte très rapidement que le matériel existant était souvent peu adapté aux exigences de notre climat et à la vie en milieu non-institutionnel.

En ce qui concerne les fauteuils roulants électriques, les systèmes de freinage étaient souvent inadéquats, les suspensions inexistantes, les engrenages entre les roues et les moteurs étaient peu adaptés à la circulation dans la neige ou sur des pentes très inclinées. Il y a aussi le problème de fiabilité de l'énergie utilisée (versus le froid), de même que l'indication de consommation d'énergie (incertitude de la distance à parcourir).

Pour ce qui est de l'aide pour les transferts, le matériel existant était fort peu conçu pour une utilisation en logement intégré. Ceci nous a obligé à faire de nombreuses adaptations de domiciles.

Au niveau de l'alimentation des outils culinaires, un bon nombre étaient disponibles pour des personnes moyennement handicapées. Pour celles atteintes d'infirmité cérébrale ou quadraplégiques, les possibilités étaient plus limitées. Des facteurs psychologiques en limitaient aussi l'utilisation.

Enfin, en ce qui concerne les aides à la communication, des progrès énormes ont été faits pour les enfants handicapés et pour les adultes atteints d'infirmité motrice cérébrale. Toutefois, pour les personnes hémiplégiques aphasiques qui restent avec des séquelles importantes après une phase de rééducation du langage, très peu d'outils fonctionnels existent pour leur permettre une communication instrumentale minimale une fois de retour dans leur famille.

Un effort concerté devra être réalisé dans le domaine de la recherche appliquée pouvant servir les personnes handicapées. De plus, les découvertes découlant de ces recherches devront être transférées au secteur de la production et de la distribution. Trop souvent, des innovations importantes demeurent dans les universités et centres de réadaptation, faute de moyens de production et de distribution.

Les coûts de ces appareils sont souvent élevés et les consommateurs devant en profiter ont des revenus très limités. Les groupes privés et associations de consommateurs devraient faire pression pour qu'une partie des coûts de ces appareils soit payée par les gouvernements.

Dans l'implantation de ces nouvelles technologies, il nous faudra apporter une attention particulière à la formation et à l'entraînement du personnel, quant à l'utilisation de ce matériel. Les impacts psycho-sociaux découlant de l'utilisation de ce matériel pour les usagers, devront aussi être étudiés.

Des inventaires systématiques de ce qui existe pour les simples consommateurs sur le marché commercial, peuvent souvent rendre accessibles différentes aides techniques et ce, à des coûts minimes. Ceci a également pour avantage, si on prend les produits vendus par les grandes chaînes de magasin, d'éviter à la personne handicapée de continuellement avoir à revenir à un centre de réadaptation, en raison de la proximité géographique de ces établissements commerciaux.

PERSONALITY INVENTORY OF PHYSICAL HANDICAP

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ABSTRACT - This paper intends to investigate certain personality traits of physically handicapped by a set of personality inventory questionnaire. Most of the evidence proved that specific personality deficit may not relate to the physically handicapped. While lower self-confidence and weaker ego-strength may correlate with the physically handicapped.

RÉSUMÉ - Cette communication veut étudier certains traits de la personnalité des handicapés à l'aide d'un ensemble de questionnaires visant à dresser un bilan de la personnalité. La plus grande partie des résultats obtenus indique que si l'on peut établir une corrélation entre la réduction de la confiance en soi et l'affaiblissement du moi d'une part et l'handicapé physique d'autre part, il peut ne pas en être de même pour des déficiences particulières de la personnalité.

While assisting in the psychological rehabilitation of physically handicapped, the therapist should recognize the outside world perception toward handicap and clear the personality characteristics of the handicapped. Some stigmatizing stereotypes are prominent in modern society. People with disabilities are said to dream of great fantasy, but to do little in accordance with their reality. They are thought to cope with inferiority by overdeveloping of discontent and resentment. Disability is believed to disturb the whole personality because it strikes at the core of the self, the body image.

The purpose of this study is trying to investigate certain personaltiy traits of the handicapped. The method is applying psychological test (personality inventory) for experimental groups (handicapped youth and adult) in comparison with control groups (non-handicapped youth and adult). The measurement consists of a set of questionnaire (K.M.H.Q. = Ko's Mental Health Questionnaire 1977) which divided into 11 subscales. Fifty subjects are randomly chosen from those who are paraplegic (mostly from sequelae of poliomyelitis), receiving pre-service training in Taiwan Provincial Southern Vocational Center. The same numbers of non-handicapped trainees are chosen as the control groups. Group testing is administered for both groups at the same time.

The results of variable analysis (2x2 : handicap - non-handicap; youth - adult) on K.M.H.Q. show that the statistical differences between handicapped and non-handicapped are significant of subscales IV (self-confidence), $F(1,96)=4.75$, $P<.05$ and X (ego-strength), $F(1,96)=6.4$, $P<.05$. The differences of age variables (youth - adult) on subscales II (hypochondriasis), $F(1,96)=8.01$, $P<.01$; V (inferiority), $F(1,96)=4.78$, $P<.05$; VI (anxiety) $F(1,96)=6.07$, $P<.05$ are significant. Scores on subscales III (asocial) and VI (anxiety) are influenced by the interaction between variables of age and handicap, but that of I (suspicion), VII (obsession), XI (independence), VIII (sexual inhibition) and IX (aggression) are not influenced.

Moreover, followings are the results of after-event comparison on each subscale of 4 groups (handicapped youth and adult). The difference between handicapped groups on all subscales is not-significant; but difference between handicapped and non-handicapped adult on subscales IV and IX is significant.

In summary, the scores of handicapped youth and adult on self-confidence and ego-strength are lower than that of non-handicapped. It is said that the handicapped are lack of self-confidence and ego-strength. The scores of suspicion, obsession, independence, sexual inhibition and aggression about the handicapped are not significantly higher than that of non-handicapped. It seems that if handicapped persons could accept their reality for vocational training, they don't have more psychiatric symptoms than that of control groups.

We conclude that it fails to reveal any definite correlation between specific personality characteristics and specific body conditions. It is recommended that if the therapist can assist the physically disabled in counterpropagandizing misconceptions about themselves, it will help them cope well with their life in such an irrational world. Finally, successful management of the stress of handicap often strengthens self-confidence and ego function that indicates the maturity of personality.

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SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 5

INDEPENDENT LIVING I - HOME AND WORK SITE MODIFICATIONS/
VIE AUTONOME I - MODIFICATIONS AU FOYER AT AU TRAVAIL

INDUSTRIAL SEWING MACHINE MODIFICATIONS TO ENABLE EMPLOYMENT

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ABSTRACT - A knowledge of local industries is useful to special aid service groups in helping disabled workers find employment. A large local garment industry prompted the modification of two industrial sewing machines to enable disabled operators to obtain full-time employment.

RÉSUMÉ - Lorsqu'ils connaissent les entreprises locales, les groupes dispensant des services spéciaux peuvent mieux aider les travailleurs handicapés à trouver de l'emploi. Une grosse entreprise locale de vêtements a modifié deux machines à coudre industrielles afin de permettre à des opérateurs handicapés d'être employés à temps plein.

INTRODUCTION

Unemployment among disabled workers continues to be very high (1). Any effort which helps these workers to find employment is well spent.

In a special aids service program it is often useful to have a knowledge of local industry so that efforts are directed toward local employability. In the Winnipeg, Manitoba area there is a sizable garment industry with a fairly constant demand for sewing machine operators. This presents an opportunity for disabled workers to compete in a job market with support from a special aids program.

This paper describes modifications to two industrial sewing machines that enable two handicapped workers to hold full-time employment. The prospective employer was willing to hire these workers providing they could produce at a rate of at least 50% of their fellow workers.

EQUIPMENT

The two sewing machines adapted in this project were Singer model 591C 300G with four options: 1) oversize stand 2) needle position 3) back tacker and 4) under trimmer. These machines combine several operations under one control lever. In normal operation the foot pedal, when pressed down and away initiates forward sewing and progressively increases sewing speed. When pressed down and toward the operator, the pedal causes several operations to occur sequentially. The machine first sews in reverse for a fixed distance, then elevates the pressure foot, and finally activates the automatic thread cutter. In both cases discussed here, it is the method of operating the foot pedal that was modified.

CASE ONE

This man is paraplegic as a result of spinal cord injury. Thus the sewing machine has to be wholly upper limb controlled. To keep the hands free to manipulate the sewn fabric, it was decided to harness elevation and depression of the elbow to operate the sewing control.

The existing control box was moved intact to the right front edge of the table (see fig.1). A hinge is mounted on the table top with a pivoting bar attached. Two horizontal plates are mounted on the pivoting bar such that they can be adjusted and locked for required separation distance and height. The pivot bar and control box are interconnected with an adjustable linkage, most of which is original sewing machine equipment. The non-original parts of the assembly are made from cold rolled mild steel with an enamel finish for smoothness. The operator places his right forearm between the horizontal plates. Depression causes forward sewing and elevation causes reverse sewing and related functions.

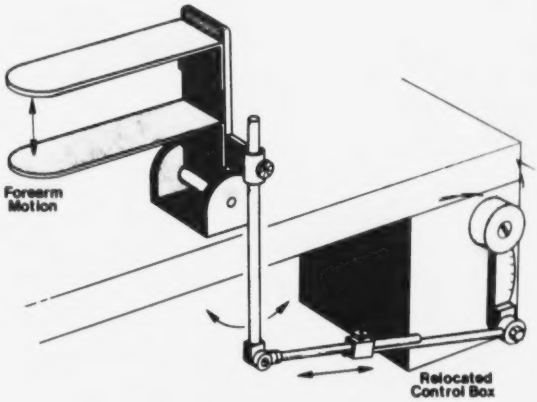

Fig1: Schematic of Modified Sewing Machine Control

CASE TWO

This woman demonstrated bilateral lower limb weakness resulting from polio. She is able to walk with crutches for short distances but is not able to actively plantar and dorsiflex her ankles for prolonged periods as required to use an industrial type of sewing machine.

It was decided to retain foot operation to allow maximum freedom of arm movement. The normal fore and aft pivot motion of the pedal was replaced with side to side rocking motion (see fig.2). This permits downward pressure of one foot to oppose downward pressure of the other foot. Fine control can be obtained without fatigue.

The modification was accomplished by adding a second length-wise bar to the table base and joining these two bars with a third one. This third bar acts as the new pivot bar for the pedal. The original control box and linkage are retained.

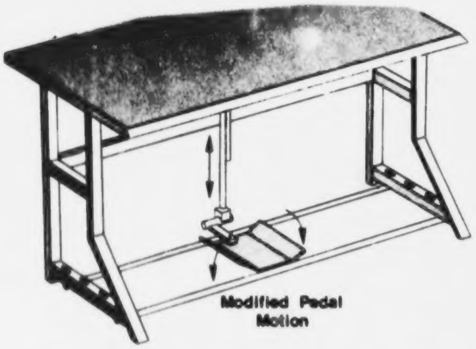

Fig 2 : Schematic of Modified Foot Pedal Operation

DISCUSSION

These two sewing machine modifications were carried out with a minimum of alteration to the original machine. Later removal of the modifications would not affect the use or resale of the machines. The modifications are highly functional but not complex. Similar work could be done by a skilled technician with the assistance of a therapist.

To be employable the two sewing machine operators involved in this study had to achieve a minimum 50% production rate compared to their fellow workers. After a one to two month period both workers were producing at a rate in excess of 80% as determined by their employer.

The success of this project depended upon many factors. The employer had to be willing to give the workers an opportunity, the workers had to have the confidence and motivation to try, and there had to be agencies to supply the consulting and technical services with no financial cost to the employer or employee. The development costs have since been recovered by taxation of the workers.

CONCLUSION

By working with local industry, it is possible to help individuals achieve employability.

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ADJUSTABLE DESK

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ABSTRACT - In Montreal's MacKay Center and other similar educational institutions, there is currently a need for mobile desks that are adjustable in height and tilt for students that are confined to wheelchairs. A full-scale prototype has been designed, built and tested.

RÉSUMÉ - Au Centre MacKay de Montréal et dans d'autres institutions de vocation similaire, il y a présentement un besoin pour des bureaux mobiles qui sont réglables en élévation et en angle d'inclinason. Ces bureaux seraient utilisés pour aider l'intégration des élèves handicapés dans les écoles régulières. À cette fin, un prototype à pleine échelle a été étudié, construit et mis à l'épreve dans un milieu scolaire.

BACKGROUND INFORMATION:

At the MacKay Center there is a program which involves assimilating handicapped students into a regular school environment. This program is extremely beneficial to the handicapped students, as in being placed in regular schools they are able to learn how to function more efficiently in society.

One of the problems in carrying out this program is that for most of these handicapped students regular school desks are not suitable. The students require a special desk that can be transported from class to class with them. Also many handicapped children do not have the necessary motor skills to write properly and, therefore, take notes with the help of an electric typewriter. Bad eyesight and very severe disabilities necessitate the tilting of the desk surface for some students.

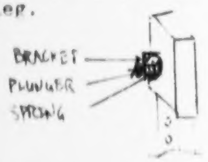
With the help of Paula Glazer and Kerry Fehr of the MacKay Center, the following design criteria were established,

1. Adjustable in height
2. Adjustable in tilt
3. Mobile in a school environment
4. Aesthetically pleasing
5. Can accommodate a wheelchair
6. Equipped with a typewriter
7. Adequate work space
8. Non-slip, easy to clean surface
9. Low cost
10. Easy to manufacture and maintain

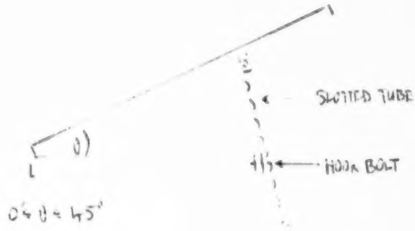
DESK DESCRIPTION:

The solution to the design problem with the preceding criteria in mind, may be broken down into the following components:

A. Height Mechanism: The desk is adjustable in height through the use of telescoping legs that lock as a spring plunger falls into holes in the inner leg.

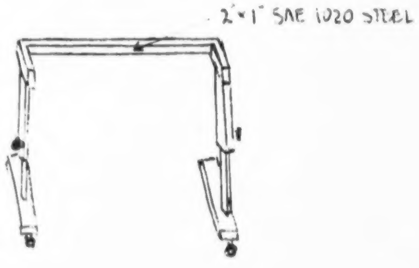


B. Tilt Mechanism: The tilting of the desk top is implemented by hooking a slotted, steel tube onto a bolt protruding from the back of the main frame. The tube is attached to the desk top by two L-shaped braces and the desk top is screwed to hinges welded to the frame.

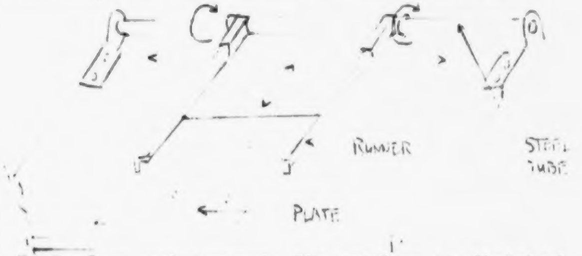


C. Wheels: The use of lockable rubber casters permits mobility in all directions. Positioned at each corner, they provide a stable and stationary surface for writing and typing.

D. Frame: The frame consists of tubular 2 x 1 inch SAE 1020 steel. An effort has been made to minimize weight and cost while keeping the structure strong. The large U-shaped section is open at the front in order to allow more room for the student's legs and wheelchair. This is in turn supported by two inverted T-shaped telescoping legs onto which the wheels are bolted.



E. Typewriter Fixture: The electric typewriter is screwed to a lockable, aluminum plate that slides between two wooden runners. These are attached to a steel tube that can move on a fixed rod secured across the back of the desk top. The fixture may be moved laterally or longitudinally on the surface. Lifting the assembly radially upwards makes it possible to remove the typewriter from the surface so that it is easily cleaned, and can be used for other purposes.



F. Surface and Armrest: The surface is finished pressboard that is easily cleanable and aesthetically pleasing. A removeable 8" x 5" non-slip mat is placed on the desk top to retain reading materials when the surface is at an angle. An armrest slides out from under the desk top on a sliding mechanism.

G. Book Shelf: A wooden box open at the top and front, with interior dimensions of 6" x 8.5" x 11" is attached to the right side of the frame. It serves as a bookshelf and can be easily removed.

CONCLUSIONS:

This adjustable desk was designed, built and tested with the help of various McGill University Mechanical Engineering professors, advisors and technicians, as well as therapists and teachers at the MacKay Center.

The desk was tested for periods ranging from a couple of weeks up to three months at a time at the MacKay Center and various other schools in the Montreal area (Keith Elementary School and l'Ecole Victor Doré). The enthusiasm with which it was received and the praise it was granted was gratifying and encouraging to the McGill students involved. Staff at the MacKay Center say that the desk is better than any other available to the school.

Feedback from teachers, therapists and students over the past year led to the following design improvements which will be implemented on the production model of the desk.

1. A twin book shelf will be placed on the other side of the desk.
2. A small retainer ledge for pencils will be placed along the edge of the desk surface.
3. A sturdier desk surface will be provided by using 3/4" instead of 5"8" thick finished pressboard.
4. The stability of the desk will be improved by obtaining a closer fit between the inner and outer tubes on the legs.
5. Stronger height adjustment braces will be used.
6. Larger diameter casters will be used to facilitate moving the desk into and out of elevators.
7. The desk legs will be modified so as to permit the entire desk to fit inside a 24" x 36" x 8" box.

Patent action has been initiated on this project. Marketing and manufacturing research was performed during the Spring and Summer of 1983 by the design team and the Centre d'Innovation Industrielle de Montréal at l'Ecole Polytechnique de l'Université de Montréal.

An order for 18 desks has been received from the MacKay Center. This order is being filled by Medical Systems Inc. of Montreal.

THE DEVELOPMENT OF A TESTING STATION FOR THE ASSESSMENT OF PHYSICAL SKILLS OF HANDICAPPED ADULTS

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ABSTRACT - Human factors data, collected on a sample of multi-handicapped adults, provided the basis for the development of a wheelchair accessible testing station, adjustable in height, and work and viewing surface angle. The station optimizes planning of work station layouts and performance on tests of physical skills.

RÉSUMÉ - A partir de facteurs d'adaptation humaine, recueillis auprès d'un échantillon d'adultes multihandicapés, on a pu définir l'assise sur laquelle repose l'élaboration d'un poste d'essai de fauteuil roulant dont la hauteur et l'angle de la surface de vision et de travail sont réglables. Ce poste optimise la planification de la disposition du poste de travail, de même que le rendement des appréciations des aptitudes physiques.

The process of developing and evaluating an assessment of physical abilities for developmentally handicapped and multiply handicapped adults illuminated the need for a specialized assessment station. It was discovered that optimal performances could not be elicited, as conventional testing environments hindered or precluded the completion of certain tests, particularly by severely handicapped individuals. The development of a specialized testing station would alleviate the aforementioned difficulty, as well as provide a basis for new tests and administrative procedures.

The physical assessment encompasses a wide variety of areas including visual abilities, motor concepts, manual skills, tactile abilities, eye-hand coordination, strength and endurance, mobility, posture, transfers, range of motion and human factors testing. The results of the assessment are used 1) to identify areas where remediation is needed e.g. optometric examination, physiotherapy, 2) to monitor progress or regression of physical abilities, 3) to match the clients' skills to task requirements in a vocational or residential setting, 4) to design work station layouts, 5) to develop jigs or aids to compensate for motor deficits, 6) to increase staff and client awareness of capabilities and limitations.

Based on the test items and administrative procedures, the following criteria were established. The work surface of the test station must be adjustable in height and angle as well as being fully accessible to ambulatory and wheelchair bound clients. A viewing surface was required that could be set at various angles and to which test material could be easily affixed. In addition, it was required that the station provide the capability to measure functional work area and to accommodate the various test jigs used during assessment.

Further design considerations and constraints included the necessity of using neutral colours and avoiding highly reflective surfaces to minimize visual strain and distraction. Adjustments had to be easily performed by a single assessor in one location and without tools. Portability and collapsibility were required due to limited storage capacity and variable assessment locations. Safety, stability and durability were definite considerations in assessing handicapped individuals, as well as low cost and maintenance requirements.

Human factors data was essential in determining the necessary range of adjustability, the dimensions of the station and the factors affecting the support structure that could be devised. Available data on able-bodied, wheelchair users and the elderly and handicapped was utilized (Dreyfuss 1960; Goldsmith and Selwyn 1976). However, as it is essential that the station accommodate extremes of the disabled population, human factors testing was conducted on a sample of 10 clients representing the more extreme cases likely to be encountered. Data collection was done in an artificial test situation using a test buck and was videotaped. Results were notably different from previously available measurements (Dreyfuss 1960; Goldsmith and Selwyn 1976) and revealed significant design implications.

The final design and finished product fulfilled the initially established criteria. The station features.

1) a two part collapsible welded steel structure made of 1" X 1" and 1" X 2" hollow steel tubing

2) a 810 X 1220 mm table surface, adjustable in height from 680 - 960 mm

3) adjustable test frame and auxiliary surfaces

   i) test frame accommodates auxiliary surfaces, is adjustable in 5° increments from 0° - 80° and can be positioned at variable depths on table surface

   ii) double sided 810 X 810 mm auxiliary test surface

      side A - gridded formica
      side B - velcro cloth over cork

4) gridded functional work area study surface made of two hinged 810 X 810 mm panels of gridded formica

5) removable arm support to provide support and extend the work surface when necessary

6) removable screen to occlude vision when required

7) casters on one side to ease positioning of station

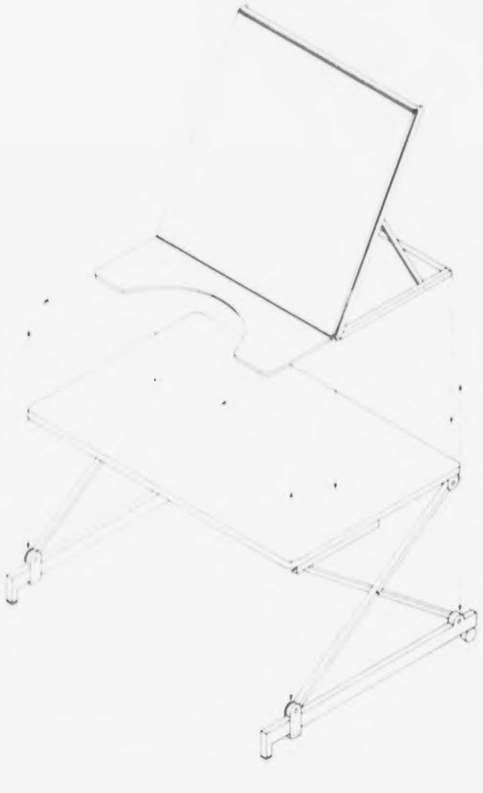

DIAGRAM 1. Assessment Station

The assessment station allows a severely disabled individual to be tested at a work surface set at a height, angle and position uniquely suited to his/her capabilities. These settings may be tested by the assessor in order to design or make recommendations for environmental layouts or adaptations. In addition, the easy adjustment or work surfaces facilitates test administration procedures.

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RELIABILITY OF DEVICES MEASURING PHYSICAL ABILITY

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ABSTRACT - Importance of physical performance measurement within job analysis techniques were discussed. Devices measuring such physical abilities need to be reliable (accurate and consistent). Modern statistical approaches were suggested to compute the reliability of the data obtained from these devices.

RÉSUMÉ - L'importance de la mesure des performances physiques dans le cadre des techniques d'analyse des travaux est abordée. Les dispositifs qui mesurent ces capacités physiques doivent être fiables (précis et stables). Des méthodes statistiques modernes ont été proposées pour calculer la fiabilité des données obtenues grâce à ces dispositifs.

INTRODUCTION

Job analysis has been a major factor in determining worker qualifications for hiring and promotion. Since the passage of the Rehabilitation Act of 1973, job analysis has gained an increasing attention in performance evaluation and hiring of persons with physical and mental disabilities. Smith and Armstrong (1980) indicate the legal and economic concerns that employers have concerning the evaluation and employment of the persons with disability. An obvious interpretation of the Rehabilitation Act of 1973 is that employers should not discriminate against employment, advancement, training, transfer and termination of individuals solely on the basis of their physical disability. This creates a need to measure attributes of physical performance.

Traditional medical diagnosis of physical disability seems to be inadequate and ambiguous when applied to physical requirements of industrial tasks. It appears that the use of human functional performance measures is a more reliable approach in determining relative physical ability. This approach is particularly useful in designing industrial environments compatible with worker capabilities and job (task) requirements.

Human performance literature contains numerous methods for measuring physical abilities. A major disadvantage of all the proposed techniques and devices has been that of little empirical research on their reliability. Malzahn (1979) describes the use of the Available Motions Inventory (AMI) to measure a person's physical capabilities in terms of his/her quantified motor behavior. The AMI consists of 142 subtasks which are typically required in performing jobs in an industrial setting. The subtasks are evaluated by a strength, accuracy or rate of performance scoring system. The following is the application of a statistical procedure to measure the reliability of the AMI and the steps to generalize this approach to other techniques measuring physical performance.

RELIABILITY

Reliability is an important factor in determining the usefulness and the applicapability of a measuring device or technique. The operational definition of reliability reflects the consistency and reproducibility of an observation (score) or set of observations. Reliability is typically estimated by a correlation coefficient. This correlation coefficient reflects the agreement between two sets of observations, obtained from the same sample of people, using the same measuring device. Lack of reliability, however, might be the result of 1) an inadequate sample of the attributes measured (a design consideration), 2) lack of skill on the part of the user (a standardization consideration), and 3) lack of stability in the attributes measured (Landy and Trumbo, 1976). The most widely used approach to obtain an estimate of reliability is to obtain test and then retest scores from the same set of individuals over a period of time called "test-retest" reliability. The correlation between the two sets of scores is the estimate of the reliability.

The simple correlation coefficient is sufficient for the devices which measure only one physical or motor function attribute (one independent variable). Most probably, a device for measuring physical functional capacity involves several independent variables of strength, reaction time, etc. Further statistical complication is introduced when there is no indication of orthogonality among the independent variables.

CANONICAL CORRELATION

Canonical correlation is a technique for analyzing the relationship between two sets of variables (Kshirsagar, 1972). Each set may contain several variables (e.g., test and retest variable scores). Simple and multiple correlation are special cases of canonical correlation in which one or both sets contain a single variable.

Given two sets of variables, canonical correlation finds a linear combination from each set, called a canonical variable, such that the correlation between the two canonical variables is maximized. This correlation between the two canonical variables is the canonical correlation. Canonical correlation can be performed using mainframe statistical computing packages such as SPSS (1975), BMDP (1974), and SAS (1982).

AMI RELIABILITY

The objective was to obtain a final measure of accuracy and consistency (reliability) of the entire AMI evaluation system. Test-retest reliability of AMI was computed using PROC CANCORR (canonical correlation procedure) within SAS. Each test and retest data matrices contain 142 subtasks performed by six subjects. Table 1 is a condensed result of the SAS printout.

TABLE 1

Results of AMI Canonical Correlation Analysis

Canonical Correlation	Canonical R-Squared
0.850815	0.723886

F Statistic	Numerator D.F.	Denominator D.F.	Prob. < F
18.1044	25	492	0.00001

The test-retest correlation of 0.85 was highly significant ($P<0.05$) and was considered to be very high in the area of human behavioral and functional measurement. These correlations are seldom above 0.8 due to the variance introduced by the inherent instability of human performance.

Another proposed statistical model parallel to canonical correlation is factor analysis (Gorsuch, 1974). The original test and retest data matrices were subjected to factor analysis using SAS package. The resulting factor scores from test matrix were then correlated with the resulting factor scores from retest matrix. The correlations were added due to the orthogonality of factor scores. The final test-retest correlation was found to be 0.74. Again, this correlation was significant ($P<0.05$).

CONCLUSION

The high test-retest reliability of the AMI is an indication that the device is able to reproduce several measures of physical functional performance accurately and consistently. Also, canonical correlation analysis and factor analysis are appropriate statistical methods for computing the reliability of devices measuring physical performance.

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A PHILOSOPHY OF ABILITY EVALUATION FOR TASK MODIFICATION

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ABSTRACT - This paper summarizes a philosophy for evaluating human abilities when the objective is to alter the environment to fit within these abilities.

RÉSUMÉ - Cette communication résume une philosophie d'évaluation des aptitudes humaines lorsque l'objectif est de modifier le milieu en fonction de ces aptitudes.

INTRODUCTION

The primary mission of the Rehabilitation Engineering Center at Wichita State University is to modify work sights for persons with severe physical disabilities. An evaluation system for quantifying physical ability has been developed called the Available Motions Inventory, Malzahn and Kapur (1980). The philosophy of ability evaluation incorporated in this system is the topic of this paper.

Most of the more sophisticated ability evaluation systems have been developed within the medical community or within rehabilitation training centers (Botterbusch, 1979). In both cases the ultimate objective of the system is to document that the individual has changed because of the intervention of the agency. That is, that the individual has changed so that they might be able to meet the requirements of their environment. Our background in Human Factors Engineering allows us to focus on a different objective, that of altering the environment has been designed based upon the assumption of "normal" abilities of the users of the environment without explicitly defining a taxonomy of these abilities or measures of them.

DEFINITION OF ABILITY

Ability is defined as the capacity to perform a fundamental task. This is not precise because the definition of what constitutes a fundamental task is left open. It is necessary to differentiate between an ability and a skill. A skill performance is the result of the integration of several more basic abilities (Fleishman, 1974). Abilities and skills may also be differentiated by the relative impact of training on performance, with skills being affected more by training than abilities. Abilities may also be assumed to be more stable over time than skills. Although a conceptual distinction can be made between abilities and skills, the ultimate classification depends upon the objective of measurement.

Most of our clients have had no experience in an environment that allowed them to develop industrially relevant skills. Therefore, our objective is to evaluate an individual's performance using a more fundamental ability scheme that provides information relevant to task modification.

PURPOSE OF ABILITY MEASUREMENT

There are two general reasons for measuring ability; the first is to compare an individual with another individual or population, the second is to compare the relative ability levels within the same person. These can be termed inter-individual and intra-individual ability comparisons.

Both kinds of comparisons can be used for task modification. The ability level of individuals who have successfully performed a task can be used to determine whether a client possesses specific abilities at sufficient levels for similar successful performance (Hanman, 1951). This is an inter-individual form of comparison.

In modifying a task, it is very helpful to know what particular ability the client possesses to a greater extent than other abilities. A modification would take advantage of this relatively higher ability level by utilizing it to design the modification around. This is an intra-individual ability comparison. We view task modification as the transformation of task requirements to these abilities that the client possesses to a higher degree.

TYPES OF ABILITY MEASURES

Three types of ability measures will be discussed; 1) percent of norm, 2) population percentile, and 3) standardized score. By far the most common form of ability measure is the simple percent of norm. This is the ratio of an individual's performance to a standard yielding a unitless measure. This kind of measure does not take into consideration the relative variability of different abilities. In other words, performing at 50% of norm has very different implications depending upon the kind of ability being evaluated.

A second common form of ability measure is a population percentile. Another form of this measure is the T-score. This is a high quality measure only if the population to which it is compared is quite well known. The method which this measure is usually calculated assumes that the distribution of ability is a normal distribution. Rarely is this assumption validated. In measuring the ability level of an individual with some form of impairment, the calculation of a population percentile is even more questionable since small deviations from normality can produce large differences in probability estimates derived from the tails of the distribution.

The third form of ability measure is a standardized score (Ebel, 1974). This is calculated by dividing the difference between the observed score and a population mean by the standard deviation of that population. The result is a unitless measure that does not require that the nature of the normed population be well defined. It takes into consideration the difference between observed and expected performance (as does the percentile measure), and the inherent variability of the specific ability in the population (as does the population percentile) without assuming that the distribution of the ability within the population is well defined. This third form of ability measure is the one that we recommend.

AN INTERVAL SCALE OF ABILITY

In our work accurate and meaningful information regarding an individual's ability is essential. The demonstration of no performance of a particular ability is just as important as the demonstration of a high level of ability. Many common ability measures such as reaction time, error rate, and visual acuity have scales in which smaller numbers indicate better performance and "no performance" cannot be indicated as part of the scale. Theoretically, no performance on a reaction time test would be coded as infinity and it would be impossible for the fastest of individuals to record a zero. We have inverted these measures to that "no performance" is a zero. For example, instead of measuring reaction time in units of seconds/reaction we would use reactions/second. Zero is now a meaningful measure. All of our ability measures have scales of this form can then be used for inter-individual ability comparisons.

In order to compare abilities at an intra-individual level; or for that matter compare different kinds of abilities, the scales must have the same units. This is a fairly simple process of standardizing the scores on the different ability scales that does not require an assumption of a normally distributed variable.

INTER- AND INTRA-INDIVIDUAL DISTRIBUTION OF ABILITIES

The distribution of a particular ability within a population is very sensitive to the nature of our population membership. For example, most strength norms are stated in such a way that they are age and sex dependent. If we limit the membership of the population sufficiently, it has generally been assumed that ability levels within the population will be normally distributed. We feel that this is a somewhat artificial means of specifying population membership. We have defined our standard population as adult humans, regardless of sex or age. This is a more realistic basis for generating a measure of level of ability required for successful accomplishment of a task, rather than a measure of how we would have expected an individual of a particular sex and age to perform if they were not disabled.

If we take adult humans as our norm population, we find that most abilities are not normally distributed; some are bi-modal, some are highly skewed, and some are close to uniformly distributed. The standarized scoring procedure discussed above allows the generation of measures without regard to the shape of the distribution.

The distribution of abilities within an individual has not received much attention. As a society we have been much more interested in comparing individuals. It has been known for some time that each individual can demonstrate very different levels of abilities. That is, that being very good at one thing does not necessarily mean that you would be good at another. A more accurate definition of intra-individual ability variation is an essential part of rational task modification.

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A STRATEGY FOR ASSESSING THE EFFECTIVENESS OF JOB MODIFICATIONS

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ABSTRACT - A strategy for rapidly evaluating the effectiveness of a job modification is described which employs a single-subject experimental design and uses a microcomputer to monitor performance. A case study is presented to illustrate the utility of this approach.

RÉSUMÉ - Cette communication décrit une méthode pour évaluer l'efficacité d'une modification dans les conditions d'un travail. Cette méthode emploie un plan expérimental à sujet unique et un micro-ordinateur pour surveiller la performance. Un exemple typique est présenté pour illustrer cette méthode.

The development or improvement of a job modification or other assistive device by a rehabilitation engineer is a lengthy trial-and-error process involving numerous changes. This paper presents a model to assist the engineer in rapidly assessing the effectiveness of various job modifications, thereby reducing development time. The model was developed by behavioral psychologists and is used in clinical settings to assess the effects of behavioral interventions. It also appears to be suitable for evaluating rehabilitation engineering interventions.

The approach incorporates a single-subject experimental design and the use of a microcomputer to monitor and evaluate performance on a job task. The basic strategy of the single-subject design consists of three parts. First, a target behavior is selected and observed to obtain a stable or baseline estimate of the performance level. Next, a treatment (independent variable) is introduced and performance is observed until it again stabilizes. Finally, the treatment is withdrawn and performance is again observed until it is stable. If the treatment is effective, performance should improve when the treatment is introduced and worsen when the treatment is withdrawn. The dependent measure is typically some index of response rate.

Although there are a number of alternative single-subject research designs, the one just described appears most suited for use by rehabilitation engineers. As this model is applied to the engineering setting, the treatment would be the introduction of or change in some type of assistive device and the dependent variable would be a measure of the response rate of whatever behavior the device is designed to improve (e.g., mobility, communication, etc.).

This approach addresses two problems with which the engineer should be concerned when evaluating a device designed to aid the handicapped. The first problem relates to the fact a client's performance on a task may be improving simply due to learning. If this fact is overlooked, one could erroneously conclude that an increase in performance resulted from the introduction of a job modification when, in fact, it was due to the learning process. The second problem is essentially the opposite of the first. When a new assistive device is first introduced, performance may not improve immediately because the individual has not yet learned to make effective use of the device. Thus, one might conclude that a device is not effective when it would be, if additional practice with it were provided. The use of a single-subject research design, as proposed, can provide the engineer with information relating to changes in current performance level or trend, and thus can allow one to avoid either of these problems.

A case study example. The subject in this study was a 20-year-old male with cerebral palsy resulting in hemiparesis of the left arm and shoulder. This man was being evaluated to determine his potential for success as a postal service mail handler and to determine whether job site modifications would increase his chances for successful job retention.

A job analysis was conducted and appropriate equipment was obtained from the local post office to create a realistic job setting at the assessment center. The job analysis revealed that one of the primary job duties of a mail handler involves sorting letters into a mail rack using "zip codes." Consequently, considerable effort was expended to assess the client's ability to perform this task and to increase his capacity at the task with a number of job modifications.

Initially, the client was given several practice sessions at the task without the benefit of any job modifications. An Apple II+ microcomputer was used to monitor his performance during these and all subsequent sessions. The computer monitored the client's performance via a game paddle attached to the mail rack. The client pressed the paddle after sorting each bundle of 30 letters. The computer calculated the time used to complete each bundle, stored this information, and plotted the data on a graph on the computer monitor. The client completed 30 bundles of letters for the first several sessions and 25 bundles per practice session thereafter.

Figure 1 depicts the client's performance under various conditions. As can be seen, the figure includes data from the first (#1) and fifth (#5) sessions of the baseline period, and from sessions evaluating five separate versions of a mail sorting tray. The first thing to note in the figure is the dramatic improvement during the baseline period, presumably due to learning. Also of note is the absence of any trend in the data for the final baseline session, suggesting that performance would not improve significantly beyond that level due to learning. At that point, the first job modification (Mod 1 - the first version of the mail sorting tray) was introduced. This led to a slight decline in performance and there was no evidence of a learning trend. Then the second (Mod 2) and third (Mod 3) versions of the tray were developed. These modifications also had little effect upon performance. However, after the introduction of the fourth (Mod 4) and fifth (Mod 5) versions of the tray, increases in performance were obtained which were approximately 15% higher than that obtained during the baseline period. This level of improvement was considered acceptable for competitive placement so no further modifications in the device were attempted. The device was then installed at the post office where the client was placed.

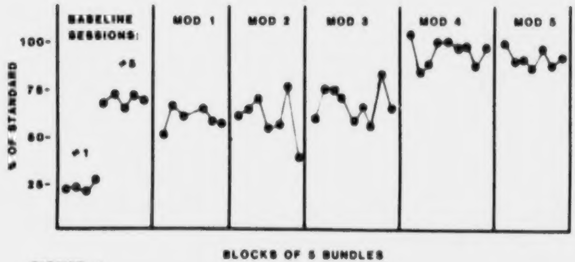

FIGURE 1

It should be noted that the assessment procedure in the case study deviated slightly from the single-subject design that we presented above. Ideally, a baseline period would have been interspersed between each version of the job modification device. However, due to the clinical application, this was not done. Nevertheless, the conclusions to be drawn from the data indicate that the use of this approach resulted in a considerable savings of time during the development of this device. This approach proved beneficial in this study and can be applied in a wide variety of other situations in rehabilitation engineering.

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DEVELOPMENT AND EVALUATION OF 4 SHOWER PROTOTYPES

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ABSTRACT - Four shower prototypes have been developed for use by severely disabled people. The designs are being finalized through evaluation and modification at the Atlanta VA Medical Center. This paper presents the features of the showers and outlines the evaluation process.

RÉSUMÉ - Quatre prototypes de douches ont été développés pour les handicapés. On termine les dessins par l'évaluation et modification au Centre Médical des Anciens Combattants d'Atlanta. Ce mémoire présente les caractéristiques des douches et explique la méthode d'évaluation.

Introduction

Four functional shower prototypes have been developed to allow independent, or nearly independent, usage by people with paraplegia, quadriplegia and hemiplegia. These prototypes were the results of sponsored research conducted at Virginia Tech from 1976-1980. The project, "Design of Bathroom Fixtures and Controls for the Able-bodied and Disabled," was sponsored by the Rehabilitation Services Administratiion and the National Institute for Handicapped Research.

This research is currently being sponsored by the Veterans Administration Rehabilitation Research and Development Service and is being conducted by the Atlanta VAMC and Georgia Tech. The goals of the work are to finish development of the fixtures, evaluate their usage and prepare them for manufacturing and marketing.

The Four Shower Prototypes

I. The Cushioned Shower

This shower is designed for people who can transfer with little or no assistance. It is covered with a 1/2"(1.3cm) foam, vinyl skinned cushion. The seat area is 19"(48cm) high and is designed to hold the user in place by providing very good buttock and back support. Part of the seat is relieved to reduce skin pressure. The grab surfaces are a combination of vertical grab bars that allow hooking by the arm and contoured surfaces that limit hand slippage. Water flow is controlled by a Bradley handi-tap metering valve and temperature is controlled by a pre-set anti-scald valve.

II. The Roll-In Shower

This shower is designed for people who cannot transfer. It consists of two enclosure sections, one a base unit that measures 36" (91cm) by 48" (122cm) by 26" (66cm) high and the second a three sided wall unit also 36" (91cm) by 48" (122cm) by 26" (66cm) high. By having these two components, the shower is capable of being installed in existing housing (it will pass through 2'-6" [76cm] doors), in new construction, and in homes where attendant care is needed. This latter usage is accomplished by installing the unit with only the base section and using movable shower curtains for the walls. The water controls for this shower are the same as those used in the Cushioned Shower.

III. Stall Shower With Molded Seat

This shower features a molded seat that has been designed to hold the user in place much the same way as the Cushioned Shower seat. This seat, however, is designed to be added to existing stall showers. It is fabricated in fiberglass but could be manufactured with a cushioned material. In addition, a clear space below the seat allows the wheelchair footrests to pass under the seat.

IV. Two Seat Stall Shower

This shower has two identical seats on opposite sides of the unit. Vertical and curvilinear grab bars are located on the front and rear walls to assist in entry, exiting and bathing stability. The seats are contoured to hold the user in place. A special footrest is located on the rear wall to assist body stability.

The Problem

The four showers were developed from design criteria compiled during the early phases of the RSA research. This criteria (Malassigne, Bostrom 1978) had two deficiencies; the subject population was very young (mean age 28.2 with a maximum age of 52) and it was limited to three physical conditions of disability; Quadriplegia, Paraplegia and Hemiplegia. Because very little testing has been conducted on the showers, we do not know how well they function. In addition, we do not know if people with other physical disabilities can safely use the showers.

The Goals

In order to evaluate the design and to complete the development of each of the showers, the following issues must be addressed: useability; safety; range of possible users; appropriate design elements; user satisfaction; advantages over conventional fixtures, and necessary design modification.

The Methods

Because we are primarily concerned with user-oriented design, it is most appropriate to evaluate each of the fixtures in terms of human criteria - specifically human performance, accident frequency and subjective responses (McCormick, 1976). To measure these criteria, environmental design research techniques developed by Templer (1983) have been adapted. As a result, the following data collection methods will be used: the success or failure to accomplish a task or tasks, time motion studies, observation of subject movement through videotape analysis and subjective evaluation through post trial interviews.

A potential subject pool of paraplegics, quadriplegics, hemiplegics, arthritics and amputees has been sent a preliminary survey questionnaire. From the respondents, actual test subjects are being selected based on their experiences with hazardous incidents (slippage, loss of balance, etc.) while bathing or, having some limitations in their bathing ability (degree of cleansing, frequency of cleansing and independence).

Subjects represent all age groups with single or multiple diagnoses of quadriplegia, paraplegia, hemiplegia, amputee and arthritis. Each subject is screened for medical problems by a VA physician prior to participation in the testing.

Each subject receives a basic level of training. This consists of studying a booklet of sketches which illustrate the use of each shower. Because all four showers appear to be very different from conventional showers the training is an important part of the evaluation. The use of a sketch media was chosen because a significant (possibly 50%) number of veterans who receive medical care are unable to read. If the subject is not able to use the fixture after studying the sketches, a second training procedure will require the subject to view a video tape which will illustrate the showers being used.

Data Collection

The data collected describes the usage of each shower by each subject. Data is developed from four sources: video tape camera, 35mm camera, data sheets filled in by the attending researcher, and post trial interviews of the subject after each trial. The video tape cameras and post trial interviews are the major source of data. Two cameras are used to record usage of each shower. One is mounted to provide an overhead view and the second is mounted to provide a frontal view. Each camera records elapsed time for use in time motion analysis and synchronization of views. The post trial interview provides important user feedback and user impression of shower usage, safety, and acceptance.

The data analysis will generate several results. Most important is a quantitative indication of the relative worth and safety of each shower. A secondary product is an indication of the worth of specific design features (such as grab bars, seat shape, etc.) on each fixture. A third product will be an indication of which designs better accommodate specific physical disabilities. Finally, there will be a qualitative indication of user satisfaction with each of the fixtures.

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COMPUTERIZED DIAGRAM AS A TOOL OF ANALYSIS FOR HAND MOVEMENTS IN GRIP FUNCTION

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ABSTRACT - From the observation of both hands of 10 workers in a working situation, a computerized diagram using the tracer CALCOMP is of interest. The authors recommend such technology in a perspective of rehabilitation and return to job.

RÉSUMÉ - A partir de l'observation au travail des deux mains de 10 travailleurs, on démontre l'intérêt d'analyser les données par ordinateur, avec le traceur CALCOMP. Les auteurs proposent cette technologie dans une perspective de réadaptation et de retour au travail.

The study of professional activities such as carpentry, requires simultaneous observation of multiple variables such as grips and pinches. In our study, the researchers used tracer CALCOMP to obtain a computerized diagram of the various hand grips and pinches in relation to the duration of each movement they had observed.

Data were examined through the direct observation of 10 workers in their own working environment whereas in other studies grips have been examined in relation to anatomy and physiology (Napier, 1956), or to the object that has to be held (Sperling and Jacobson, 1976). Five observers collected data by simultaneously observing one worker at a time during specific activities such as hammering, sawing, etc. . . . Figure I illustrates the grip movements of only one worker for a period of 27 minutes. The quadrant type division of the hand allows researchers to visualize each finger and the palm, in relation to the duration of each movement.

The results of the analysis suggest that:

- Operating strategies are of the static type for the right hand, and of the dynamic type for the left hand;
- Both hands are complementary;
- The 3rd finger of the right hand and the 2nd finger of the left hand are the most frequently used;
- The digital pinch of the 3rd and 1st fingers is the most frequently used for both hands; the tridigital pinch of the 1st, 2nd, and 3rd fingers ranks second. The digital pinch of the 1st, and 2nd fingers is less usual;
- The wrists are usually in the neutral position or in extension; this demonstrates their role as stabilizers of the hand.

These results illustrate the importance of considering the type of professional practice for evaluating hand movements in rehabilitation, for example. They also question the pertinence of currently used dexterity tests as functional tests of the hand, as they put emphasis on fine rather than on gross dexterity.

The authors conclude that the CALCOMP tracer used to prepare a computerized diagram can be a valuable tool for the analysis of complex hand movements observed in professional activities such as carpentry.

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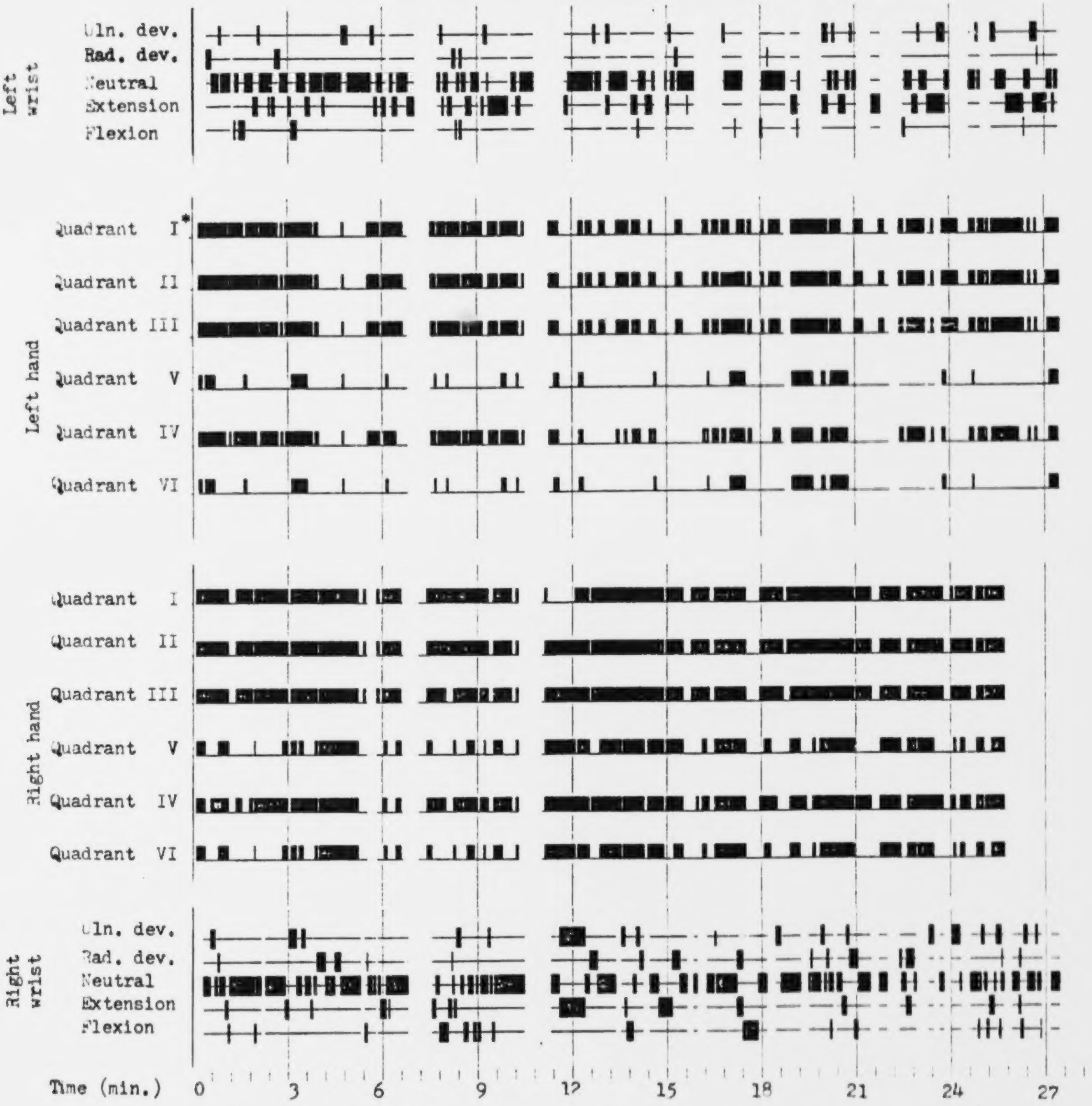
Fig 1. "CALCOMP" DIAGRAM OF GRIP MOVEMENTS FOR ONE WORKER



* Quadrant I= 1st finger
Quadrant II= 2nd finger
Quadrant III= 3rd finger
Quadrant IV= 4th and 5th fingers
Quadrant V= ulnar palm
Quadrant VI= radial palm

L'ÉVALUATION DES CAPACITÉS PHYSIQUES ET L'ADAPTATION D'UN POSTE DE TRAVAIL

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RÉSUMÉ - L'adaptation d'un poste de travail nécessite une connaissance de la personne et des exigences spécifiques de l'emploi. Cet exposé traitera plus précisément de l'évaluation des capacités de travail, de l'analyse de l'aménagement et de l'adaptation du poste de travail.

ABSTRACT - The job station adaptation request a thorough knowledge of the person and specific requirements related to the job. This statement will be dealing more particularly on the evaluation of the working capacity, analysis, arrangement and adaptation relative to the work station.

1. L'importance de l'évaluation des capacités de travail dans le processus de réadaptation professionnelle

La réadaptation des personnes atteintes de déficience motrice s'étend de la rééducation fonctionnelle à la réinsertion sociale en tenant compte d'une vue d'ensemble des besoins de la personne. Dans une perspective de normalisation, l'intégration socio-professionnelle permet à l'individu de répondre de façon autonome à ses besoins matériels et de satisfaire des besoins psycho-sociaux d'appartenance et de participation à la collectivité.

Cependant, pour réaliser l'intégration professionnelle d'une personne handicapée de façon à rencontrer les besoins de l'individu et les exigences du milieu de travail, il doit y avoir adéquation entre les capacités de travail et les tâches à accomplir. L'évaluation des capacités de travail devient donc un élément essentiel du processus de réadaptation professionnelle.

A partir de l'évaluation des capacités de travail d'une personne, les objectifs de réadaptation peuvent être précisés selon différents axes:

- viser une amélioration graduelle des capacités de travail,
- spécifier des champs d'action compatibles avec les capacités identifiées,
- adapter un poste de travail en fonction des capacités d'un individu.

Pour faciliter l'intégration professionnelle de ces personnes, une évaluation fiable des capacités de travail devient un outil d'intervention d'autant plus important qu'il devrait permettre d'éviter des situations d'échec. Les réussites dans l'orientation et le reclassement professionnel des personnes handicapées sont primordiales pour renverser les mythes et préjugés qui nuisent à leur intégration.

Au Québec, le Centre François-Charon a développé un programme structuré d'évaluation des capacités de travail pour les adultes atteints d'une déficience physique. Le programme d'évaluation est principalement basé sur des mises en situation dans différents îlots de travail. L'individu est amené à poser des gestes spécifiques de travail dans des conditions reproduisant aussi fidèlement que possible un travail donné. L'évaluation des capacités de travail couvre divers aspects de la personne (capacités physiques et intellectuelles, comportements, attitudes, personnalité, potentiel d'entraînement, motivation, etc.). Pour compléter l'évaluation, l'on peut au besoin ajouter à cette structure de base diverses autres modalités d'évaluation: soit par des tests plus spécifiques en ergothérapie, en psychologie, en orientation ou en éducation physique, soit par création d'une situation permettant la simulation d'une tâche précise n'existant pas dans les îlots de travail, soit par une observation en situation réelle de travail (stage au Centre ou en milieu de travail compétitif).

2. L'adaptation d'un poste de travail

L'intégration nécessite parfois l'adaptation du milieu organisationnel ou physique.

L'aménagement des postes est relié directement aux composantes du travail. Une connaissance préalable de la situation est donc nécessaire. L'intervenant doit porter son attention sur les exigences physiques et mentales, les exigences sensorielles, les exigences sociales et les conditions ambiantes.

Il est important de considérer certains facteurs et critères de base qui influenceront le choix de solutions d'adaptations particulières. Il est donc nécessaire d'appréhender la situation dans toute sa globalité afin que le travailleur atteigne son plein rendement tant qualitativement que quantitativement.

Des exemples d'adaptations et d'aménagements de poste de travail illustreront cet exposé.

BARRIER FREE ENVIRONMENT DESIGN IN HUNGARY

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ABSTRACT - We are making our work in connection with medical rehabilitation, on the basis of movements made by aids, activity-models, movement diagrams - together with physicians, technicians, medical gymnastics, social workers as well as with the associations of handicapped. The basis of the designing is the establishment of the space needed to fulfil the functions friction-free.

RÉSUMÉ - Nous faisons notre travail dans le domaine de la réadaptation médicale sur la base des mouvements réalisés par des appareils d'assistance, des modèles d'activité et des diagrammes de mouvements. Nous travaillons en collaboration avec des médecins, des techniciens, des spécialistes en gymnastique de réadaptation médicale, des travailleurs sociaux et des associations d'handicapés. Le fondement de ce concept est de procurer l'espace nécessaire pour permettre ~~aux~~ handicapés de fonctionner librement.

The Hungarian architectural research and practice has not individual achievements in the planning of barrier free environment and buildings, which could be of world-wide reputation.

Our activity in Hungary is carried out on the one side by the analysis of other countries proved good, by their adaptation to our circumstances, and on the other side, by the exploration of our own fundamentals, possibilities. This is partly unfavourable, owing to the fact that till now we have elaborated a barrier free environment only for a small number of human beeings, primarily living in institutes or smaller settlements, partly favourable, due to the fact that we could harmonize the experimented and proved good methods and solutions with the Hungarian rehabilitation-aspirations, with the Hungarian architectural and building prescriptions, sometimes developping them further. The concentrated and used by a relatively greater group of men solutions give us further valuable conclusions and results. These tasks, this work is not less than to find new solution, to investigate new methods. Our economic conditions and life-standards, therefore, our flat-norms are quite different, ours is more low. We consider the rehabilitation, the integration of handicapped as an important the quick and excellent results, specially in these years.

Hungary has changed many times and considerably during her history as to the territory and population as well. The territory of to-day is of to-day is of 93.ooo km2, constitutional form is: People's Republic. Her best known geographical sight is the capital, Budapest and the greates sea in Middle-Europe, the Lake Balaton. Hungarian conquest was in 896, since than Hungarian are living at this territory, now we have lo.8oo.ooo inhabitants, and some millions outside of our frontiers. As to the territorial division of the population it is characteristic, that already in epoch of the Romans 19 % of the population lived in the capital,8 % in the further greatest towns and the remaining cca 73 % are living in 3.ooo smaller settlements, towns, villages. The proportion of the dependent and inactive population is of 21 %, while the proportion of physical handicapped is at about 5oo - 6oo.ooo.

The rehabilitation in Hungary has begun in the 191o-192o years, it became an impetus in 1945 and after having linquidated the tuberculosis, it came to larger development, utilizing its network. The central institute was organized in 1966 and is functioning 1975, its network is now developping.

By the planning of the environment for the handicapped, the physically handicapped people we are starting from the development of the remaining and the newly formed capacities and the aids, helping them, and taking into consideration the totality of these factors, we make smaller changements in the envirenment, the buildings. In our activity, planning we rely upon the services making our daily life more comfortable. We are aiming at the optimal rehabilitation from the point of view of the individuals and their environment, more than the pure technical service. Therefore, we are making our work in connection with medical rehabilitation, on the basis of movements made by aids, activity-models, movement-diagrams - together with physicians, technicians, medical gymnastics, social workers as well as with the associations of handicapped. On the basis of the collected opinions and experiences we are examining our buildings and its elements, the standardized or recommended solutions of other countries. The differences shown by the comparisons we analyse, and include in the professional training, the development of capacities and media --and especielly, we are looking for the reasons of the solutions used elsewhere. Seeking for the resons of the differences, we obtained the following results:

1. According to the actual economic and social possibilities of Hungary, our primary aim is the solution of the supply, training and post-training of the more seriously handicapped, who are able to serve themselves, first of all in the framework of institutes or in settlements which have an institutional back-ground.

2. Starting from the Hungarian production-capacities, we have to take into consideration among the aids the more simple ones, which need less service and spare-parts, but can support a greater utilization, even if these can be used perhaps on a greater space.

3. The greater surface and technological supply are needed owing to the fact that in Hungary there are great differences between the wheel-chairs, produces here. There are up-to-date productions as well as some wheel-chairs produced lo years ago. At the same time, the wheel-chairs produced in Hungary are quite different as to their measures and mechonical characteristics from the types produced in other countries. The Hungarian wheel-chair stock is also very heterogen because of the individual possibilities in obtaining them.

4. The Hungarian building and building material sortiment is not so large, that the most duitable materials and constructions sholud be built in.

5. The planning is influenced also by the different micromoduls - basic modul network.

In our tasks of integration we shall take into consideration, that the basic norms and standards of flat-construction are different. We have to solve our tasks primarily within the framework of the average construction of 52-56 m2 . With a bank-credit one can build an appartment of 12o-14o m2, and as these flats are also taken into the average, one can see the extension of our task. Thus our flat-planning attitude is to assure a minimal hygienic and other conveniences and a greater useful surface. Now a day we leave the needs of an "Average Man" and try to stress the needs which are different, in our planning work. The basis of the planning is the establishment of the space needed to fulfil the functions friction-free.

Beyond our results in the rehabilitation, in the last time we give more and more institutes, schools and training-employing workshops for the handicapped. In 1983 the first settlements, built for physically handicapped were built, in the form of State and co-operative flats.

Our main aim in rehabilitation is - with the activ co-operation of the handicapped, the maximal use of their state and capacities - to make them possible to use, to enjoy their objectiv environment. The aim of the adaptation is to make utilizable the objects, the buildings and its elements with the less modifications for all people, so for the handicapped too.

(Edited Version)

In Hungary we consider the rehabilitation and the integration of disabled persons as an important priority. Present day architectural barrier free design, which is such an important consideration in integration, is a mixture of both adopting the best concepts generated in other countries and carrying out our own design research. Although our practical experience has only been gained from a small number of installations, primarily in institutions and small communities, the experience has been valuable in developing new solutions and methods.

The population of Hungary is 10.8 million, of these 73% live in 3000 small communities, towns and villages. The disabled population is estimated to be between 500 and 600,000. To serve the needs of the disabled a centralized rehabilitation institute was established in 1966 and began functioning in 1975. A network of expertise is now being developed and a team approach is being encouraged in assessing the needs and capabilities of disabled persons. The team includes associations of the handicapped, physicians, technicians and medical gymnasts and social workers.

Some of the constraints and considerations which we must apply when delivering services include:

1. The use of simple aids which require less servicing and stocking of spare parts.

2. The limited choice in building design and building materials.

3. The lack of standards for items such as wheelchairs.

4. The limitation imposed by the presently used modular construction methods (an average apartment module is 56 m^2 in area).

WALKING TALL: A CRUTCH DESIGN FOR PERMANENT USERS WITH AESTHETICS AS A PRIMARY CRITERION

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ABSTRACT - This paper describes a new forearm crutch which was designed to fulfil the functional requirements and enhance the personal image of the client. Consideration was also given to the user's need of carrying parcels or bags in their hands.

RÉSUMÉ - La présente communication traite d'une nouvelle béquille ajustée à l'avant-bras qui a été conçue pour satisfaire aux besoins fonctionnels du client et pour rehausser son image personnelle. On a aussi tenu compte du besoin de porter des sacs ou des colis dans la main.

Design Criteria

The primary physical criteria were the needs for: 1) strength; 2) durability; 3) ergonomic consideration; 4) lightweight, and 5) comfort. Specifically, three vital areas in the forearm crutch required special attention: 1) the rubber end tips had to be long lasting and secure, providing stability in conjunction with flexibility and friction; 2) the hand grips had to be ergonomically positioned, comfortable and secure; 3) the forearm cuffs had to pivot with movement, flex to avoid arm injuries, be comfortable, durable, and secure.

To address the client's specific needs, the functional and aesthetic elements of the crutch design would have to be given equal weight. To personalize the walking aids, there would be no integrated adjustability, and the client's handgrips would be cast. Casting was possible since her grip did not change in shape or position during movement. For versatility the forearm cuffs (at present made of leather) would be made of durable canvas, and be removable to afford change; in that way, various coloured cuffs would complement different outfits. Coordinating with the forearm cuffs would be detachable canvas saddle bags secured at their tops and bottoms, preventing movement of them, and allowing the user to carry small articles easily. Since they are removable, they would be designed so each could be used as a knapsack.

Again considering aesthetic values, radial elements and smooth transitions would be employed in the crutch body. The main crutch would be gloss black, enhanced by the various coloured forearm cuffs and saddle bags when in use. The use of fibre-reinforced plastic would provide the crutch with strength, durability and lightweight in combination with a quality finish.

Final Design

The primary design criteria were implemented as follows:

1) Strength was achieved through the choice of material and form. The aluminum shaft was carried through to the handgrip where the members were welded securely. The joining of the main shaft to the circular element was done through a 95.0 mm length where the 21.0 mm O.D. aluminum tubing was fitted into and welded to a 25.0 mm O.D. piece of aluminum tubing.

The circular element below the handgrip distributed the applied stress.

Fibre-reinforced plastic was chosen for its characteristics of lightweight, resistance to chemicals, high tensile strength, good weathering properties and high dimensional stability.

Finally, strength was obtained by making the crutches a one-piece molded part with an aluminum insert.

2) Durability resulted from the characteristics of the materials themselves. Fibre-reinforced plastic is currently used in a wide range of products (e.g., canoes, mailboxes, packaging, light and radar domes, aeronautical and automobile parts), all of which demand durability.

3) Ergonomic data were easily obtained. The performance of the currently marketed crutches were found to be satisfactory. Therefore, all measure-ments were taken from existing wooden crutches and transferred to my design. (Note: In mass production, the aluminum shaft would be at maximum length and later cut and filed to specifically required lengths. Other dimensions do not require alteration (e.g., the distance from the handgrip to the forearm cuff and the horizontal distance between the crutch arms).

4) Lightweight was achieved through material selection (fibre-reinforced plastic and aluminum) and by use of the minimum amounts necessary.

5) Comfort was mainly considered at the handgrip. Here the product's finish became vital. It was smooth with a glossy surface to prevent unwanted hand burns. Casting of the user's actual handgrip was intended to enhance comfort. The gloss black finish was chosen to add to the crutch's elegance and to provide a neutral accessory upon which the user's wardrobe need not depend.

The circular component evolved from studies in stress distribution, as well as the need for a plane from which to drape the saddle bags. The purity of form lends visual ease. The flaps of the saddle bag echo the circular element of the crutches to maintain consistency. The included photographs show the prototype as employed by the user (Fig. 1), with the use of a saddlebag (Fig. 2). From the photographs, it should be noticed that the functional aspects of the crutches themselves were not altered. The integration of the saddlebags onto the crutches, however, does contribute to improved function. Aesthetic improvements should be evident.

The total weight of the crutches was 1.8 kg per paid compared to 1.4 kg per pair for the wooden version. Their retail cost is estimated at $70 per pair compared with $35 for the wooden version.

Acknowledgements: The author wishes to thank Ms. Nancy E. Hensen for suppling the idea for the project and for her user expertise. Also thanks to Dr. J. Michael Lee, Biomaterials Research, University of Toronto.

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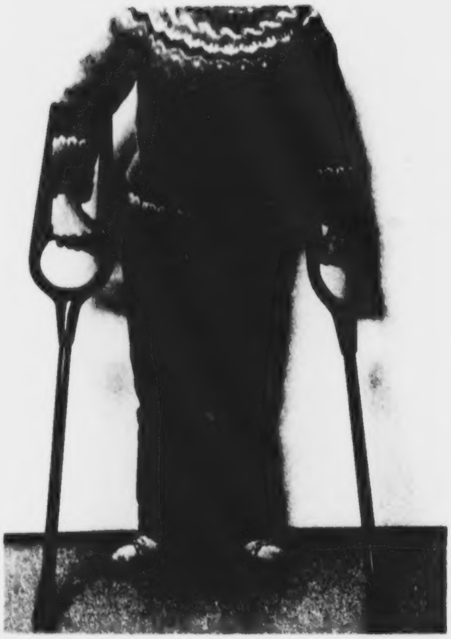

Fig. 1 A close-up of the new crutches

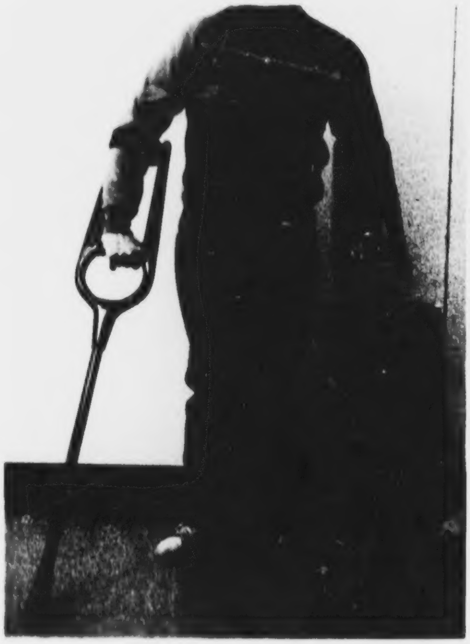

Fig. 2 The saddle bag attached to the new crutches

A NEW MANUFACTURING METHOD OF A COSMETIC GLOVE

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ABSTRACT - The present paper deals with a new manufacturing method of a symmetric cosmetic glove to a residual hand of a handicapped person with one hand cut off. The equipment developed in this study can measure the residual hand, manage the measured data and mill a model of a glove, easily and automatically. This technique will certainly be used in the rehabilitation field besides a glove.

RÉSUMÉ - Le présent mémoire porte sur une nouvelle méthode de fabrication d'un gant esthétique symétrique adapté à la main lésée d'une personne handicapée. L'équipement mis au point dans le cadre de cette étude permet de mesurer la main lésée, de gérer les données mesurées et de façonner un modèle de gant facilement et automatiquement. Cette technique sera certainement utilisée dans le domaine de la rééducation fonctionnelle.

1 - PURPOSE AND SYSTEM - Most handicapped persons with one hand cut off are dissatisfied with the form of cosmetic gloves on the market. Moreover, there is no good glove fitted for the mechanism of an electric arm. The glove manufactured in this study satisfies these demands.

Recently, the automatic measuring technique with a 3-dimensional coordinate measuring machine has been incorporated in the field of CAD(Computer Aided Design). However, this technique is difficult to apply in a complicated object like a hand. Therefore, new equipment was developed with a view to measure the hand form, manage the measured data and mill a model of a glove, automatically and easily. Consequently, this study has been advanced to lay stress on the development of a 3-dimensional drive machine, a computer hardware, a touch sensor for the living body and software for measuring, data managing and milling. Fig.1 shows this system. The host computer is used to manage the data and control the slave computer. The slave computer is a 3-dimensional numerical controller provided for a DDA(Digital Differential Analyzer) to drive the drive machine. The drive machine is used to measure with a touch sensor, draw with a pen and mill with a cutter.

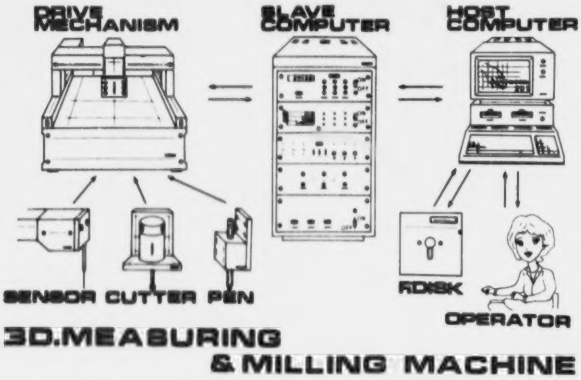

Fig.1 The system to manufacture a glove

By using this system, the automatic measuring of a complicated object (hand, arm, foot, leg) which was regarded as a very difficult technique in the past is possible. And the various data managements, graphic displays and millings according to the measured data can be done automatically, easily, and freely.

2 - MEASURING - To measure a soft object like a hand, a non-touch sensor is to bo hoped for, but a touch sensor can measure with more accuracy and in a shorter time and with a simpler method.

In this study, the capacitance type touch sensor with a needle prove(Length:50mm, Diameter: 0.5mm, Responsibility:10pF) is used and measure by the point-to-point method. Simple passes of the sensor(model data) are made for the hand from the wrist to the finger by the host computer by cross sections. And the model data transported to the slave computer. The slave computer controls the drive machine with a DDA according to the model data, and stores the x,y and z values touched by the sensor and transports the measured data to the host computer by the cross sections. The data are filed in a floppy disk. This method gets about 1,000 points of data taking in about 30 minutes and the accuracy is ±0.02 mm. Fig.2 shows the measured cross sections of a hand.

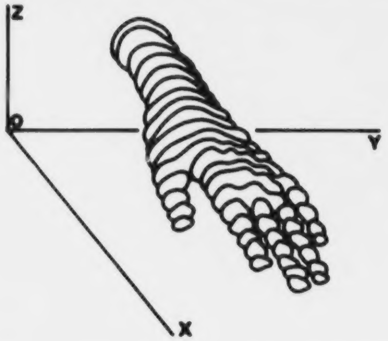

Fig.2 The measured cross sections

3 - MANAGING OF THE MEASURED DATA - In this process, a symmetric transformation and a interpolation about for the measured hand form take place. There is no problem about the symmetric transformation from the residual hand to the affected hand, because it is the same as a transformation of a coordinate system.

A B-spline interpolation and a ellipse interpolation are used to get minute details because the hand form got by the measuring has rough points at 3-8 mm intervals and it is inpossible to mill a model directly. The interpolation in the measured cross section and during the cross sections is done with a B-spline interpolation. It is very difficult to interpolate a complicated object like a hand which contains 5 fingers, but it is possible with the use of a new algolism developed by this study with a B-spline. An ellipse interpolation is used to get a suitable roundness of the finger chips. This method of interpolation is very simple and suitable for a hand.

By this interpolation, more details of the hand at 1-2 mm intervals(about10,000points) are got automatically by the host computer with BASIC language. Fig.3 shows a measured and managed hand form which was drawn by this system.

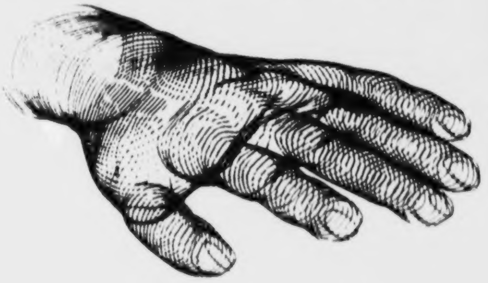

Fig.3 The measured and managed hand form

4 - MILLING - A model of a glove is milled making use of the hand form got by the data management.

The hand form is divided into an upper side and a lower side form to mill a cube material (wax or plaster). The respective milling data are made after an interference check and a correction of a cutter. The milling data are transported from the host to the slave computer. The slave computer controls the drive machine with a ball nose cutter which has a diametor of 3 mm. At first, the upper side is milled, and next the lower side is milled after turned over the material. The milling goes forward from the wrist to the finger by 1.8 mm intervals. The model of a glove is completed after cutting the wrinkles and the nails by hand.

Fig.4 shows the model of the glove manufactured by this system. Then a copper model is made to use the model as a mandrel by the method of electroforming. At last, the glove is got by the molding of a silicon rubber. The cosmetic prosthesis is shown in Fig.5.

Fig.4 The model of the glove

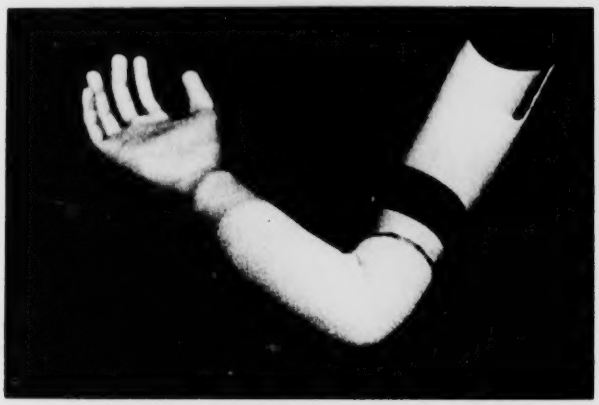

Fig.5 The cosmetic prosthesis

4 - CONCLUSION - The cosmetic glove fitted for the handicapped person is manufactured by this system automatically. As a result, it is possible to measure every part of the body with the same way as measuring a hand. And a transformation to a glove form which is suitable for the mechanism of an electric arm will be possible by the application of the CAD technique with the measured hand form.

The automatic measuring, managing and milling technique developed by this study will certainly be used in the rehabilitation field.

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CABLE-DRIVEN CHAIRLIFT SUITABLE FOR INSTALLATION ON AN INTERNATIONAL 656 OR FORD 8000 AGRICULTURAL TRACTOR

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ABSTRACT - This paper describes a chairlift which allows a handicapped farmer to get from his wheelchair into the tractor operator's seat. The chairlift operates from the tractor battery and uses a winch and cable to pull the seat assembly up a track to the operator's seat.

RÉSUMÉ - Cette communication traite d'un dispositif permettant à un cultivateur handicapé de se hisser depuis son fauteuil roulant jusqu'au siège d'un tracteur. Le dispositif est branché sur la batterie du tracteur; le siège et le conducteur sont hissés à l'aide d'un treuil et d'un câble le long d'un rail jusqu'au siège du tracteur.

Introduction

The purpose of the project described in this report was to design a versatile cable-driven chairlift for a paraplegic farmer. The chairlift described is suitable for mounting on either an International Harvester 656 or Ford 8000 model tractor with only slight modifications.

The cable-driven chairlift is composed of four major parts: a seat assembly, a drive track and its supports, a cable, and a winch.

With the design presented, a farmer can build a simple chairlift utilizing existing tchnology and locally available resources which he can use on his tractor. With this lift, the farmer will have greater independence to carry on the operation of his farm tractor and thus complete essential farm-related tasks.

The Design

This project uses a chairlift design in which a winch and a cable are used to pull a handicapped farmer up to the tractor operator's seat along a track. The farmer can control his ascent and descent along the track with a switching box, and the seat assembly will automatically stop at the top and bottom of the track with contact limit switches. The design of this chairlift was developed by starting with the track and the necessary supports and proceedings through the switching that is used on the chairlift.

Track

The track, shown in Fig. 1, is located on the right side of the IH 656 (left side on Ford 8000). This allows a non-handicapped farmer to use the tractor without interference from the chairlift since the steps on the tractor are located on the left side. With the track on the right side, it is convenient for both the handicapped and non-handicapped farmer to use this tractor. The track and the bearings are both made by Uni-Strut and are readily available from the manufacturer.

In order to prevent decreasing the resale value of the IH 656, the track was assembled to an upper and lower support, which are attached to the tractor using existing bolts holes instead of cutting or drilling into the tractor. In order to prevent the bearings from binding in the track, the bearing plate (with the factory-made bearings positioned in the plate) is placed into the track and allowed to roll freely the entire length of the track. The track is positioned in a jig and the Uni-Strut pieces are spot welded to the mudguard and then to the angle irons of each support. This prevents the track from becoming distorted and makes the assembly of the track to the supports easier. After the pieces have been spot welded, a fillet weld is placed at each contact point.

Upper and Lower Support

The upper support is mounted to the back axle of the tractor, (On the Ford 8000 it is attached to the Roll-Over-Protective-Structure.) It is made with an angle iron which it attached to a square plate which is bolted to hot-rolled 1020 square tubing. The lower support is attached to the tractor chassis. The lower support is made with an angle iron which is welded to a channel iron which, in turn, is bolted to the chassis of the tractor.

Motor and Cable

The American Society of Agriculture Engineers (ASAE) standards require that the lift be able to pull up farmers of all weights up to a maximum of 280 pounds. This lift design uses a 12-volt DC winch to pull the farmer up the track. The expected pulling force of the winch selected is 2000 pounds. The winch is connected to the tractor battery which provides the power for the winch. The winch is bolted to the motor mount which is bolted to the track. (See Figure 2).

The cable connects the winch to the seat assembly. A 7 x 7 strand-core cable is used in this design. The cable is five-thirty seconds of an inch in diameter and the test breakage weight on this cable is 2400 pounds.

Seat Assembly

Bearing Plate, Mounting Plate, Pivot Plate

The bearing plate is the foundation of the seat assembly. The Uni-Strut bearings are press fitted into the bearing plate. With the bearings, the bearing plate is able to roll up and down the track. The bearing plate, like all of the steel used in this design, is made with hot rolled 1020 steel.

The mounting plate is placed in a jig and welded to the bearing plate, and the pivot plate is pinned to the mounting plate.

The pivot plate is pinned to the mounting plate with a three-eighths inch bolt and a spacer. The seat is attached to the pivot plate with mounting brackets which are spot welded to the pivot plate.

Seat and Seat Lock

The seat used in this design is the minimum size ASAE seat. Any set will work in this design. The seat frame is bolted to the mounting brackets which are attached to the pivot plate.

In order to prevent the farmer's legs from being caught in the track while he is in motion, the seat swivels. He can ride up the track with his legs on the outside of the track, and when he gets to the top of the track, he can rotate the chairlift seat to get into the operator's seat. To prevent the seat from rotating when the farmer doesn't want it to, a seat locking device is used.

The seat lock consists of six components: a handle, a pin, a spring, a spring mounting chamber, a handle support, and a lever arm. The lever arm is welded to the handle. The pin is positioned in a hole in the lever arm and the spring is attached to the upper part of the pin which is housed in the mounting chamber. The seat locking assembly is mounted to the pivot plate and operates by allowing the pin to fall through a hole in the pivot plate into one in the mounting plate and thus preventing the seat from rotating.

The farmer can rotate the chairlift seat by easily depressing the handle. This will pull the pin out of the hole in the mounting plate and unlock the seat. Once the farmer has rotated the seat to the desired position, the pin will spring into another hole and lock the seat down.

Switching Box and Contact Switches

The normally-closed momentary contact limit switches are wired in series with the switching box, the motor, and the battery. The contact switches have a spring-loaded lever arm on them that when touched by the bearing plate, will momentarily break the circuit and shut the winch (motor) off. These switches are located at the bottom of the track and about one-half the distance up the track. The switches will automatically stop the seat at the bottom of the track or at the same height as the operator's seat.

A safety device is located at the bottom of the track. This device is a bolt that is placed below the bottom contact switch and is used to stop the chairlift seat in case the cable or connections would fail.

The contact switches are wired to the switching box (which is attached to the right arm of the chairlift seat) so the farmer can switch on the winch and go up or down and stop automatically at the top or the bottom of the track.

A key switch is optional. This can be mounted to the left arm of the chairlift seat. The farmer can use a key to shut off the entire system when he is not using it. This is a safety device to prevent unauthorized use by children or others. A complete installation is shown in Figure 3.

LIST OF COSTS AND COMPONENTS

Track	$ 63.00
Winch	178.00
Cable and clamps	5.00
Bearings	10.00
Upper Support	40.00
Lower Support	22.00
Seat with bearing plate and attachments	44.00
Switching Box	90.00
Normally closed momentary contact limit switches	117.00
Wiring and hardware	10.00
Total	$579.00*

*Note: This price assumes that all of the parts were purchased. The total price will be reduced if some of the parts are made from available stock. This price is also a rough estimate and will vary depending on where the parts are purchased.

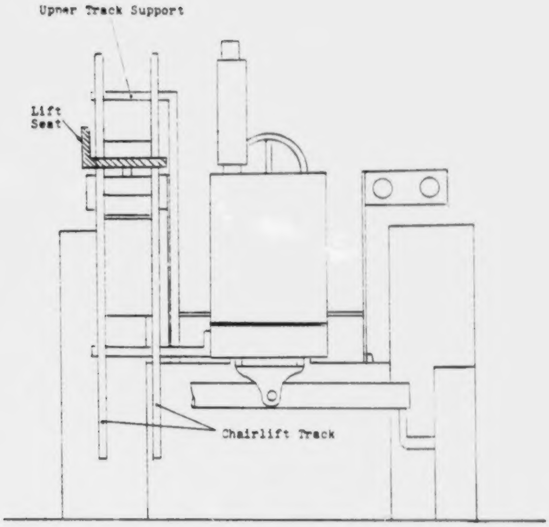
Upper Track Support
Lift Seat
Chairlift Track

Figure 1. A Front View of the Chairlift on the tractor

Figure 3. Chairlift on Ford 8000

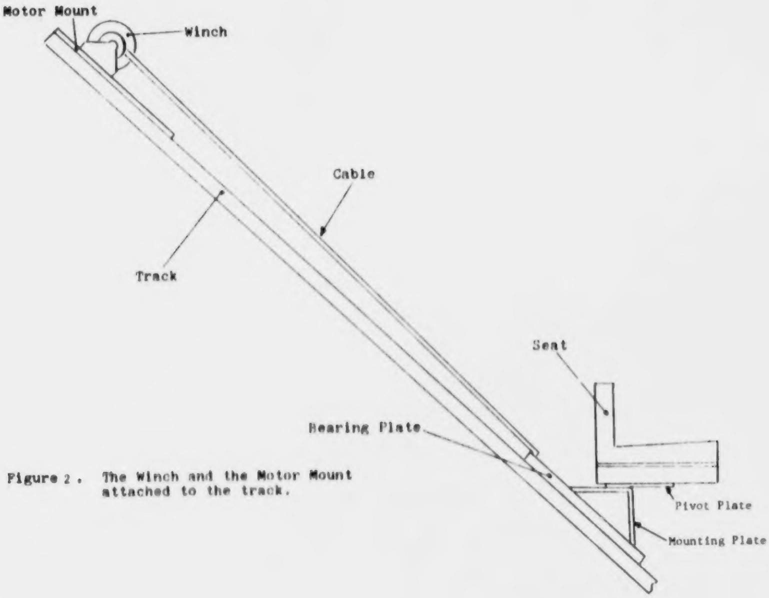
Motor Mount
Winch
Cable
Track
Seat
Bearing Plate
Pivot Plate
Mounting Plate

Figure 2. The Winch and the Motor Mount attached to the track.

SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 6

COMPUTERS II - ADAPTATIONS AND APPLICATIONS/
ORDINATEURS II - ADAPTATIONS ET APPLICATIONS

ASSESSMENT OF COMPUTER SKILLS AT THE PEARSON COMPUTER CENTRE

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ABSTRACT - An assessment procedure, developed at a computer centre catering to the severely physically disabled population of British Columbia, is presented. This assessment incorporates word processing, basic computer theory, computer programming, and aptitude testing. Client statistics for the first year of the Centre's operation are presented.

RÉSUMÉ - Un procédé d'évaluation, développé au centre d'ordinateur concernant la population de personnes sévèrement handicapées physiquement de Colombie britannique, y est présenté. Cette évaluation comprend un traiteur de texte, une théorie de base sur l'ordinateur, la programmation et un test d'aptitude. Les statistiques de la clientèle pour la première année d'opération du centre y sont présentées.

The Pearson Computer Centre was established to provide the severely physically disabled population of British Columbia with easier access to computers and computer training programs. One of the functions of the Centre is to provide an assessment of a disabled individual's potential to use a computer, primarily for vocational applications such as programming or operations, but also for recreational applications. This assessment is also used as the screening procedure by which we determine the aptitude and ability of individuals applying for admission to our training programs.

Prior to taking the assessment the client is invited to a one-hour interview at the Centre. During this interview the assessment procedure is explained, the client can get some hands-on experience with a computer, and an evaluation is made of the best method of interfacing the client with the computer. The decision, as to whether or not to take the assessment, is made by the client after this interview.

The assessment is conducted on a one-to-one basis and is composed of eight two-hour sessions spread over a four week period. Although the number and duration of these sessions can be adapted to the special needs of the client, it is this schedule that is recommended. The main reason for selection of this schedule was that the assessment is really a mini-course in computers. We provide the type of training that one would experience if they signed up for an introductory computer course. Because many of our clients had either not completed their education, or had been a long time out of the educational system, we felt the "culture shock" of the new concepts and computer jargon, as well as the academic orientation of the material, might serve to discourage some of the clients. Spread over four weeks, these people would have time to assimilate and study the material without being overwhelmed by it.

The assessment was composed of four major components:

1. Training in the operation of a word processor.

2. Introduction to the elementary theory of data processing, including basic concepts of data storage and computer architecture.

3. Introduction to programming in BASIC, including explanation of the basic system commands and the PRINT, LET, and INPUT statements, by the end of which they should be able to write a simple chequebook balancing program.

4. The writing of two aptitude tests for computer programming and operations (Science Research Associates Computer Programmer Aptitude Battery and Computer Operator Aptitude Battery).

The rationale for this arrangement was as follows:

1. Most of our clients were coming to the Centre, having heard the publicity about what computers can do for the disabled, thinking that computer programming will be an easy way out of their economic doldrums. Thus, many of our clients thought that with a microcomputer and an instruction manual they would be able to learn to program a computer and earn a lot of money. In this respect our assessment opened up alternatives by showing the client other potential applications of the computer.

2. Because programming is so complex and because it requires many steps before one gets a concrete result, we determined that a word processor would be a better beginning. In this way the client could be composing and writing letters, and thereby operating the computer, before the end of the first session. Building on successful experiences like this would increase the client's confidence as well as develop his familiarity with how computers operate.

3. Once the ability to operate the word processor had been achieved we would begin introducing the elementary data processing theory. This would act as a carry-over from the practical operation of the word processor to the more abstract area of programming.

4. Programming, being the most complex part of the assessment, was left as the last part of the mini-course.

5. Due to their complexity, the aptitude tests are administered at the end of the assessment. Again, the problems of culture shock relating to the jargon and necessity to think academically prompted us to do them after the practical aspects of the assessment.

A written report is presented upon completion of the assessment. It provides feedback on the following areas:

1. Mental Abilities:
    a) memory
    b) problem solving
    c) reading ability
2. Physical Abilities:
    a) endurance
    b) vision
    c) the best method of interfacing with the computer
3. Work Attitude
    a) punctuality
    b) ability to keep appointments
    c) attitude
    d) motivation
    e) perseverance

This is then followed by recommendations, which include whether or not to consider computers in a vocational application, and, if yes, how best to get the training necessary to achieve that vocational goal.

During the first year of operation the Pearson Computer Centre saw 57 clients. Of these, 27 came for the initial interview only, 15 were assessed from among the residents of Pearson Hospital, and 15 were assessed for referring agencies. Of these 30 assessments, 5 showed promise for computer programming, 16 were able to operate a word processor (although not necessarily at a skill level that was vocationally marketable--typing speed being the primary limitation), 6 were deemed inappropriate to program or operate a computer, and 3 were not interested or lost interest.

Summary

In the great onslaught of technology and the advances that make that technology accessible to the disabled, we must not lose sight of the need for training and the development of the human side of the technology application. In addition, characteristics such as interest, motivation, and aptitude play a big role in the success of the application. Programs that give the disabled community hands-on contact with computers and that are able to evaluate those persons' abilities to use and learn that equipment are a very important phase of the training cycle. It is only through such evaluation and training that computer technology can be properly utilized by those who need it.

COGNITIVE CONSIDERATIONS IN USE OF AN ELECTRONIC COMMUNICATION SYSTEM

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ABSTRACT - This paper outlines the cognitive skills needed to operate electronic communication systems. It provides the foundation for a discussion of the means-ends relationships and problem solving abilities required to operate interfaces and switches.

RÉSUMÉ - Cette communication décrit les aptitudes cognitives nécessaires pour faire fonctionner les systèmes de communications électroniques. Elle fournit une base à la discussion des rapports entre les fins et les moyens et des aptitudes mentales nécessaires pour faire fonctionner les interfaces et les commutateurs.

Continued technological advancements in the area of communication devices, switches and interfaces will result in the production of new communication systems. These advancements must not evolve without thorough consideration of the cognitive skills associated with operation of the communication system. Engineers and technical specialists need a fundamental understanding of these associated cognitive skills (e.g., Shane & Bashir 1980, Chapman & Miller 1980). There is a general consensus that a person must be in or through Stage V or VI of Piagetian development to use a non-oral means of communication (e.g., Shane & Bashir 1980, Chapman & Miller 1980). However, several authors have suggested that use of an electronic communication system may enhance cognitive development (e.g., Harris & Vanderheiden 1980, Musselwhite & St. Louis 1982, Chapman & Miller 1980). Cognitive areas recognized as crucial in use of a device include means-ends relationships and problem solving. This paper will outline the development of these skills and analyze the skill relationship to operation of interfaces and switches.

Piaget's theory of cognitive development divides the first two years of a child's life into six stages with approximate age limits for each of the six sensorimotor stages. However, it is the sequence of skills, not the ages acquired, which is important. This sequence can be applied to use of a switch or interface.

In stage I (birth to one month) the infant appears to be a reflexive being, but his reflexive experiences are forming a foundation for later learning. In stage II (one to four months) the infant is beginning to become a creature of habit. The infant causes something to happen to himself by chance and immediately attempts to rediscover what he did; i.e., thumb to mouth. Through trial and error, he may succeed. The infant can only sporadically imitate and repeat actions he has immediately performed or is in the act of performing.

By stage III (four to ten months) the infant is becoming more physically active and mobile. He accidentally causes something to happen on an object and attempts to repeat it. Through this stage the infant begins to learn that his actions are related to an interesting result. He then learns what movements he needs to make to reproduce the interesting result. He is best at repeating or imitating actions which are familiar.

Stage IV (ten to twelve months) marks a critical transition from accidental to intentional creation of interesting actions on objects. The infant becomes goal oriented; seeing an object and knowing what to do with it. If an obstacle prevents him from attaining his goal he can employ an indirect approach to achieve the goal. Through this development, the infant continues to employ his body as his main tool to achieve goals. It is not until stage V (twelve to eighteen months) that he consistently realizes he can use another person or tool as a direct means to achieve a predetermined goal. The infant uses an object to act on another or on a person and uses people to achieve a desired end. The reactions he receives lead him to experiment with new means or variations of old means. The infant can also systematically imitate new actions.

Finally, the infant reaches stage VI (eighteen to twenty-four months). In the previous five stages the child's behavior was primarily experimental. In stage VI the child is acquiring language and is developing the ability to think in abstraction rather than relying purely on past experiences. When faced with a problem, the child no longer must experiment with new and old means to achieve goals. The child is at the threshold of being able to think out a solution, rather than act.

Using this normal development data, it is possible to analyze interfaces and switches to determine the cognitive skills required for their successful operation on a device. Table 1 shows a summary of the development of means-end relationships as it relates to tool use and the requirements of a switch or interface.

Table 1

Tool Use = TU
Switch/Interface Requirement = SIR

Step 1:
  TU=self acts as tool, must see tool and immediate, direct result
  SIR=use body part which child can use, body is the interface on a device
Step 2:
  TU=uses tool, but must see tool and immediate, direct result
  SIR=use interface on body part which child can see, make contact with device
Step 3:
  TU=can begin to separate tool from direct, visible contact with body
  SIR=use interface on body part which child can not consistently see, but makes direct contact with device
Step 4:
  TU=can use tool indirectly, but needs to contact tool
  SIR=use a switch not directly in contact with device, but visibly connected
Step 5:
  TU=can use tool indirectly with visual feedback, but not physical contact
  SIR=use an interface not directly in contact, but which provides visual or auditory feedback
Step 6:
  TU=can reason use of tool without obvious visual, auditory or physical connection
  SIR=use an interface which provides limited feedback

Examples of interfaces, switches and accessing modes which match the cognitive requirements for operation are listed in Table 2.

Table 2

Step 1: direct selection using body part on touch sensitive surface of a device
Step 2: direct selection with body-held sensor which contacts device
Step 3: headstick, mouthstick, chinpointer
Step 4: tread, lever, rocker, touch
Step 5: viewpoint optical indicator, brow switch, voice activated switch, focused light with light sensor (hybrid)
Step 6: light sensor

Individual interfaces and switches, other than those listed in Table 2, can be analyzed according to the cognitive skills required to use them effectively. Continued research is needed to determine whether switch selection facilitates means-ends and problem-solving development. Information obtained must be compared to other skills which develop during the sensorimotor period of development, including imitation, sequencing and object permanence. Each of these areas also plays a critical role in the development of communication with an augmentative communication system. Finally, all information on normal cognitive data must be compared to data on the cognitive development of a physically impaired child. Inability to act on the environment will affect cognitive development and create learning differences. Only by fully understanding the coordination between cognitive development and device usage can appropriate electronic communication systems be created.

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THE ACTIVITY BOARD

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ABSTRACT - This paper describes the Activity Board, a special expanded keyboard designed for use with disabled children who may need introduction to keyboarding skills or who are unable to access a regular keyboard. The Activity Board works in conjunction with electric toys or other battery operated equipment.

RÉSUMÉ - La communication que voici nous introduit à la carte "Activité", un clavier spécial surdimensionné conçu pour les enfants handicapés auxquels on doit enseigner les rudiments de l'utilisation d'un clavier, ou qui ne peuvent faire usage d'un clavier normal. La carte "Activité" est utilisée pour actionner des jouets électriques ou d'autres appareils à pile.

BACKGROUND

During a number of visits to special education classrooms in various school districts and other institutions throughout the province of B.C., it became increasingly evident that a large number of children in these settings required a great deal of time wih teachers in order to master simple concepts. In most cases, this meant a large amount of individual attention from the teacher, and very often the reinforcement given was in the form of a favorite toy or other object familiar to the child. Many children did not respond to verbal reinforcement alone. In one such case we observed a teacher attempting to identify a simple object in a picture. Once the child pointed to the correct object, the teacher would reach over and switch on the child's favorite toy, in this case a battery-powered monkey that played the drums. Verbal reinforcement was also given by the teacher, but it was evident that for the child, at this stage, it was not enough to consistently produce the desired response. This meant not only that a great deal of one-to-one time with the teacher was necessary, but that the teacher spent a great deal of time switching the toy on and off. Another implication was that the teacher would have to work with each child in the classroom in succession in order to produce the desired effects. Many children we observed were as yet unable to deal with fairly low-level concepts and certainly were unable to operate a conventional keyboard. One teacher in Nanaimo expressed a desire to see an expanded keyboard that could be used for teaching a variety of concepts or ideas and that could be hooked up to a battery-operated toy. The Activity Board was developed shortly thereafter.

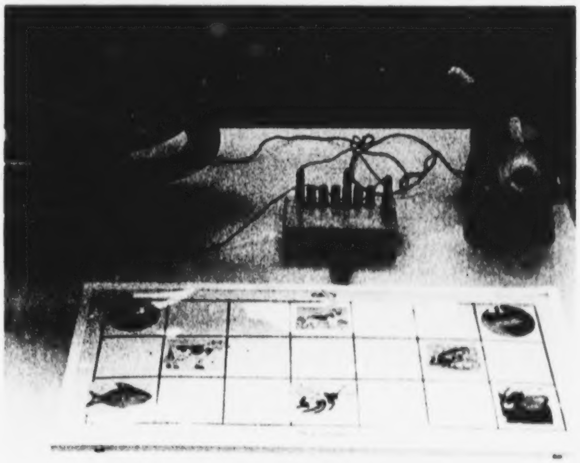

Fig. 1 THE ACTIVITY BOARD

DESCRIPTION

The Activity Board was designed for use with disabled children who may need introduction to keyboarding skills or who are unable to access a regular keyboard. As a teaching tool, it can be used to introduce and reinforce a number of important concepts or ideas. The Activity Board can be used with children having severe mental and/or physical impairment, motor dysfunction, visual impairment or learning difficulties.

Measuring 12" x 24" x 1", the Activity Board consists of 21 three inch squares on a 7 by 3 grid. The connections to the squares are brought out to a small box on which are mounted ten terminals (7 x 3). These squares are covered by a sheet of clear plastic, held in place by reusable tape. The clear plastic can be peeled back and any pictures, symbols, letters, numbers, colours or shapes may be placed under the plastic. To select a particular square, the user simply connects one plug from the reward toy to the appropriate socket on the top of the control box and the other plug to the appropriate socket on the side of box. Any battery operated toy or other gadget can be used and will be activated each time the correct square is pressed. Adaptation of toys for use with the Activity Board is very simple.

Often the child will have a favorite toy or gadget that he/she has shown a particular interest in. This can be used to reinforce other desirable activities, such as recognition of numbers, letters or pictures. The Activity Board is extremely versatile because multiple overlays can be created for use with several students; in this way, different tasks or subject areas can be accomodated. The keyboard can be set so that touching it anywhere will activate the toy. In this way the child can learn that his/her actions produce a desired end result. It can then be set so that touching the one half of the keyboard will activate one toy or device and touching the other half will activate a different toy or produce no action. In this way the child can be introduced to the concept of choice. Once this concept is established the 21 three inch squares may be used. If verbal reinforcement is desired, this can be introduced as a next step by connecting the Activity Board to a battery operated tape recorder.

The Activity Board is also available in a 10 x 4 format consisting of 40 two inch squares; with this format, the entire alphabet, as well as numbers or other symbols, can be displayed. These keyboards may be used only with battery operated equipment, toys, etc., and must under no circumstances be used to switch line operated equipment.

CONCLUSION

Three months of field testing conducted by special education teachers and other rehabilitation personnel produced very favourable feedback, and the Activity Board was then put on the market. It is now commercially available through Contemporary Artistic Technology Co. Ltd., P.O. Box. 58430, Stn. L, Vancouver, B.C., Canada V6P 6K2 and from T.A.S.H., 70 Gibson Dr., Unit 1, Markham, Ontario, Canada L3R 2Z3.

ACKNOWLEDGEMENTS

Developmental work for the Activity Board was supported by a grant from the British Columbia Health Care Research Foundation to Dr. Peter Graystone at the School of Rehabilitation Medicine at the University of B.C. Special thanks are also due to the Wesbrook Society for their funding.

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LIGHT DISPLAYS TO AID IN REMEDIATION OF NEUROBEHAVIORAL DEFICITS

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ABSTRACT - This paper describes two electrical devices developed to assist those who have suffered either cerebral vascular accidents or head injury. The devices' primary purpose is to aid in the remediation of and adaptation to the neurobehavioral deficits of unilateral neglect and impaired visual memory.

RÉSUMÉ - La communication que voici donne la description de deux dispositifs électriques qui viennent en aide aux personnes victimes d'un accident cérébro-vasculaire ou d'une blessure à la tête. L'objet principal de ces dispositifs est d'aider les malades à récupérer des déficits neurocomportementaux du genre négligence unilatérale et mémoire visuelle déficiente, ou à s'y adapter.

Neurobehavioral impairments can greatly affect the client's capacity to respond in rehabilitation and can have major implications toward eventual functional level. These two devices were developed in order to provide rehabiliation staff with additional tools for remediation, as well as provide a means for gathering data on variance in performance of rehabilitation clients. Initial evaluations of the devices indicate they are effective in remediating these deficits, and that this remediation generalizes to the 'real world.'

Visual Neglect Box

The first device is illustrated in Photo 1. This unit was constructed to aid in the treatment of unilateral neglect. In cases of unilateral neglect, patients do not attend to half of their bodies or environment. This neglect greatly hinders their rehabilitation because they are frequently involved in minor accidents and mishaps due to their inattention to only one side. Mobility, dressing, and a number of other activities are affected by the deficit.

The neglect box teaches the rehabilitation patient with unilateral neglect to develop compensatory visual scanning strategies that generalize to other situations. For this purpose, the therapist will select lights, which act as cues, concentrating on developing attention toward the neglected side. Due to the unit's width, the client must visually scan to find the 'active light.'

The unit has also been put to use in other ways; for example, short-term memory training. For this purpose, magnetic letters are attached to the display and the client asked to repeat a sequence either verbally or by light pattern.

PHOTO 1

Simon Box

The second unit, nicknamed the 'Simon Box,' is shown in Photo 2. A block diagram is presented as Figure 1.

Like an electronic Simon game, the unit presents a sequence of four front panel lights. Unlike the electronic game version, a number of sequences are programmed and selected, rather than randomly presented. This increases its utility for training and research purposes. This device also does not utilize accompanying auditory tones, but concentrates on visual memory and sequencing without auditory cues. An additional difference is this unit does not wait for the patient to match the display before proceeding; rather, the pace is determined by the therapist, client, timer, or switch input.

The box has the capability of storing 16 different sequences, each 16 steps long.

The sequence is selected by the thumbwheel at the rear of the box. Presently, only 5 are programmed. These sequences are illustrated in Figure 2.

Both the Visual Neglect Box and the Simon Box are currently being tested in research designs. Although final determinations have not yet been available, the formative evaluations indicate both devices can be powerful tools to aid in rehabilitation.

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PHOTO 2

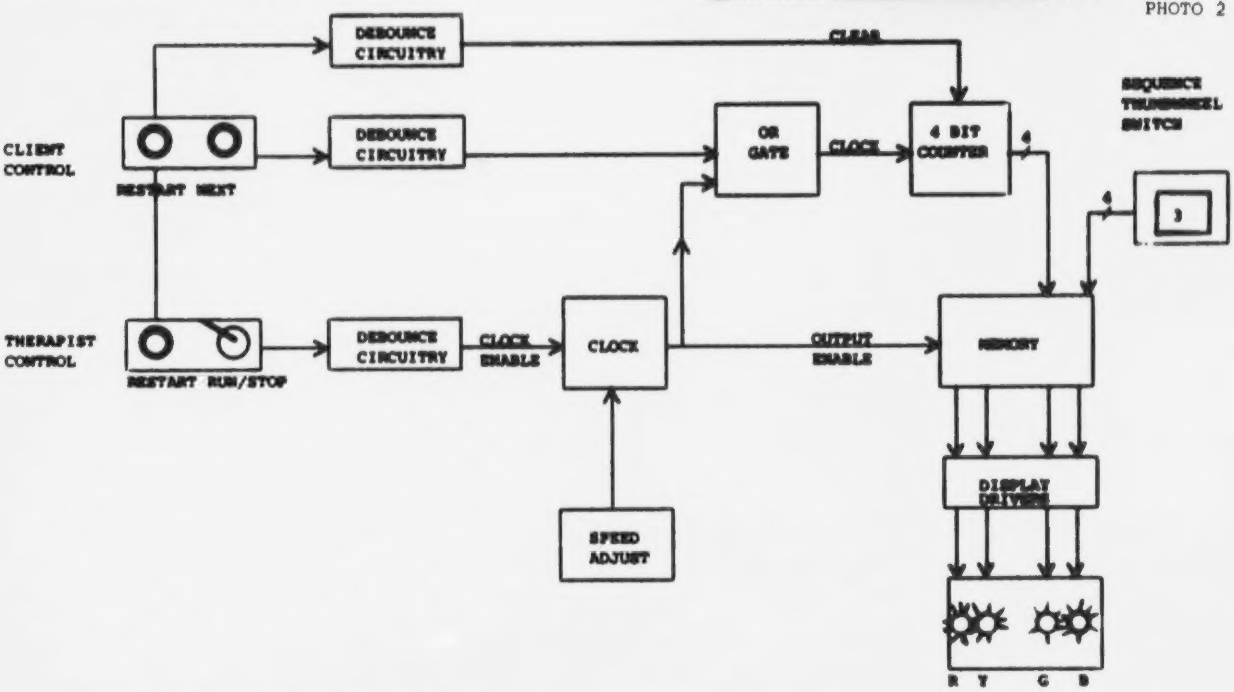
DEBOUNCE CIRCUITRY
CLEAR
CLIENT CONTROL
RESTART NEXT
DEBOUNCE CIRCUITRY
OR GATE
CLOCK
4 BIT COUNTER
4
SEQUENCE THUMBWHEEL SWITCH
4
3
THERAPIST CONTROL
RESTART RUN/STOP
DEBOUNCE CIRCUITRY
CLOCK ENABLE
CLOCK
OUTPUT ENABLE
MEMORY
DISPLAY DRIVERS
SPEED ADJUST
R Y G B

FIGURE 1 BLOCK DIAGRAM OF "SIMON" BOX

SEQUENCE 0					SEQUENCE 1					SEQUENCE 2					SEQUENCE 3					SEQUENCE 4				
STEP	R	Y	G	B	STEP	R	Y	G	B	STEP	R	Y	G	B	STEP	R	Y	G	B	STEP	R	Y	G	B
1					1					1					1					1				
2	X				2				X	2				X	2		X			2			X	
3	X	X			3			X		3			X	X	3					3				X
4	X	X			4		X			4		X	X	X	4		X			4	X			
5			X		5	X				5	X	X	X	X	5			X		5				X
6	X		X		6		X			6	X	X	X		6					6				X
7		X	X		7			X		7	X	X			7		X			7		X		
8	X	X	X		8				X	8	X				8			X		8	X			
9				X	9			X	X	9					9	X				9			X	
10	X			X	10		X	X		10				X	10					10	X			
11		X		X	11	X	X			11			X	X	11		X			11		X		
12	X	X		X	12		X	X		12		X	X	X	12			X		12	X	X	X	X
13			X	X	13			X	X	13	X	X	X	X	13	X				13				
14	X		X	X	14		X	X	X	14	X	X	X		14				X	14				
15		X	X	X	15	X	X	X		15	X	X			15					15				
16	X	X	X	X	16	X	X	X	X	16	X				16	X	X	X	X	16				

FIGURE 2
LIGHT SEQUENCE TABLE
X = Light On

DESIGNING SOFTWARE FOR THE CONTROL OF TECHNICAL AIDS

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ABSTRACT - A micro-computer based technical aid must meet a variety of needs to be of practical use to a disabled individual. By careful use of software, a high degree of flexibility can be achieved and efficiency maximized for such an aid. Factors influencing software development for a comprehensive computer-based air are discussed.

RÉSUMÉ - Pour qu'un support technique géré par micro-ordinateur soit utile à une personne handicapée, il doit répondre à une variété de besoins. Par une bonne utilisation du ligiciel, on peut atteindre un degré élevé de souplesse et accroître l'efficacité d'un tel support. On traite des facteurs qui influent sur la mise au point du logiciel pour un support complet géré par micro-ordinateur.

INTRODUCTION

A functional technical aid must meet several criteria. It must be simple to install, simple to use and flexible enough to meet the demands of many different users as well as the changing demands of a single user. This puts constraints on the design of the actual "hardware" and great care must be taken to ensure that these constraints are not reflected into the software where they can decrease the usefulness of the aid and place increased demands upon the user. The following discussion centers around software developed for a comprehensive aid. The aid is a computer based system incorporating an unlimited vocabulary speech synthesizer, BSR module controller, telephone, keyboard emulator, printer, monitor and a wide range of input devices. The function of the software is to control the operation of these peripheral devices in the most efficient manner possible while at the same time allowing the user to manipulate the system with a minimum of effort.

HARDWARE CONSIDERATIONS

The system software must be self-loading if it is to be independently operated by the user. The system is not intended to be used in a portable mode yet it should be as small as possible. It must also be simple to operate and simple to configure (minimum number of external connectors, cables and controls).

PATIENT CONSIDERATIONS

The level of service provided by the supplier of a device will affect the development of the software. If the aid is marketed without an allowance for customization, then the software may be simplified. However, some customization is always necessary if a patient is to achieve the maximum benefit from an aid. Flexibility should be incorporated into the aid's design and, ideally, a support service provided.

HARDWARE IMPLEMENTATION AND CORRESPONDING EFFECT ON SOFTWARE

In order to reduce the number of separate instrument cases and connections, the computer, BSR module controller, telephone and voice synthesizer were modified and placed in a single case 14 inches square and 5 inches high. The only external connections to the unit are: (1) the input device, which connects to a jack on the front of the case; (2) the printer; and (3) the monitor which connect to jacks on the back of the case. A step as simple as this will have important effects on the controlling software. When several devices are installed in a single instrument case they are no longer user accessible but have become dedicated units. This apparent loss in hardware flexibility can lead to an increase in software flexibility. There is no software code wasted providing options that may not be implemented by some types of peripherals. The extra memory thus created can be used to further exploit the dedicated devices.

The device must be simple to operate. In order to run a computer based device, a program must be loaded into the computer. This can be done either through the use of ROMs or alternate hardware that automatically loads a program into the system from a floppy disc upon power-up. To maintain a very high degree of flexibility and also to facilitate program development the latter method was chosen. The program can then be coded in Basic as opposed to Assembler. Changes can be easily made and new disks given to the user as opposed to having the aid returned to have ROMs replaced. Disks have the added advantage of being able to store large data files such as text, phone numbers and speech vocabularies. In addition, the operating system can be easily modified to accommodate the different physical and mental needs of a variety of users.

The printed circuit board design will also affect software requirements. An easy and convenient layout may in some cases complicate the design of the software. Consider an 8 x 8 matrix of CMOS switches that function as a keyboard emulator. The system monitor displays a corresponding matrix of symbols which, when selected, close the appropriate CMOS switches and, therefore, the corresponding key on the emulated computer. If the symbol presentation directly corresponds to the keyboard matrix of the emulated computer, any CMOS switch can be correctly selected by using two simple formulas. If there is no such direct correspondence then separate software routines will be required for the closure of each switch. For an 8 x 8 matrix, this means 64 statements will be required as opposed to two, a 32 times increase in the required code. In this example, memory requirements, execution time and program flexibility are considered first, appropriate software is written and finally the hardware is assembled based upon the software.

Software operation of peripheral devices is accomplished through the use of menus. Any peripheral device can be accessed with a minimum of two menus and a maximum of three. For example to use the telephone, the "phone" function is selected from the main menu. The phone menu will then appear on the monitor and a particular phone function can be selected (see fig 1 & 2). Thus two selections are needed. This section of the program is independent of the input device. A directed scan technique uses the same number of selections as a row-column scan, however, the directed scan is, faster, of course. Thus, two very different access techniques can be implemented with a minimum of software changes and no hardware or firmware changes. It should be pointed out that none of the changes in the operating system require hardware or firmware changes. The extensive use of menus and subroutines allows the software to assume a modular nature, much like that of the system's hardware. This gives the system great flexibility. As mentioned above, changes can be made to the operating system through software, stored on a disc and the new disc given to the user. This makes the system easy to customize for individual users. All peripheral and input devices are assigned parameters by the operating system. Changing input devices requires only the changing of a small subroutine. This permits the use of simple, more reliable input devices. The ability to change the operating system is necessary for another reason: to use software that accommodates all possible options on the system would increase memory requirements, thus reducing program efficiency and increasing the system's cost.

Flexibility is available not only to the developer, but to the user as well. Subroutines are included that allow the user, using only their input device, to change menu labelling, phone numbers and to customize a speech vocabulary, and cursor speeds.

Parameters that may be altered in the operating system by the supplier include menu formats, menu symbols, row-column or directed scan, menu information (phone numbers, vocabularies, etc.), cursor speeds and input device parameters such as joystick sensitivity, optical beam sensitivity, etc.

CONCLUSION

Feedback from people currently using the system has resulted in minor revisions to the operating system. As the user's needs change further revisions will be needed, but, because of the systems flexibility, these changes will be done easily through software rather than hardware. Although this may place more burden on the developer and supplier of the system, the level of service available to the user will ensure that he or she derives the maximum benefit from their system.

LIFE WITH THE ADAPTIVE FIRMWARE CARD

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ABSTRACT - This paper describes the experience of using the Adaptive Firmware Card with the Apple computer in a residential hospital for physically disabled children and young adults. Creative ways of adapting the card for specific user needs are detailed.

RÉSUMÉ - Cette communication décrit l'expérience de l'utilisation de l'Adaptive Firmware Card sur l'ordinateur Apple dans un hôpital pour enfants et jeunes adultes souffrant de handicaps physiques. Des méthodes novatrices d'adaptation de la carte aux besoins particuliers d'un usager sont décrites.

The introduction of the Adaptive Firmware Card[1,2] (AFC) for the Apple II computer has meant a tremendous leap forward for those unable to physically use a computer keyboard. At Bloorview Childrens Hospital, the AFC has been widely used with a residential population of physically disabled children and young adults with cerebral palsy and muscular dystrophy.

The fact that the AFC is easily adapted to accommodate a variety of physical abilities has made it most useful in an environment where every user is unique. This flexibility has meant that user needs in the area of communication, education, and leisure can be met by the computer that were never before possible. Many of these possibilities become evident after use and experimentation, and may not be obvious at first glance. It is perhaps too easy to install the AFC, use it in a single mode such as scanning, and forget about its many other capabilities. Some of these more creative capabilities as they are used at Bloorview are herein described.

SCANNING

Of the sixteen possible modes of the AFC, eight use a single switch to replace the keyboard. Of these, the group/element scanning strategy with the alphabetical arrangement has been found to be the most useful at Bloorview. Conceptually, it is the easiest switch strategy.

Custom modifications have been made to the standard scanning line for specific needs. For example, a simplified arrangement consisting of only the alphabet, with space and backspace has been customized for new users who can be confused by extraneous characters and branches. Another custom array for word processing applications places the ESCAPE symbol (used frequently in Applewriter and Bank Street Writer) in the first array with the alphabet, and all remaining characters in a second array, thus saving much of the indirect activity of branching.

Custom scanning arrangements have also been used for software programs which require only a limited number of keys for operation. For example, the program Spinnaker's Delta Drawing uses D for Draw, C for Colour, etc. These can be easily set up as a single array in logical order according to the program. Partial command sets can also be made for users learning the program.

Custom redefinition is even more powerful when a single character selected from a scanning array can input a longer string of characters to the computer. For example, LOGO commands such as DRAW, FORWARD, and MAKE, even if abbreviated, require several letters to be typed in succession. In a redefined LOGO scan, these commands could be entered by a single selection with D standing for DRAW and so on. With up to four arrays available at a given time, at least one array can be set aside for these single-key commands.

MORSE

Morse Code, while promising improved efficiency, has not been very well received among Bloorview's residents. Because of the timed coordination required, users with cerebral palsy typically find Morse more difficult than scanning. Residents with muscular dystrophy and adequate fine motor control, are potentially good Morse users. However, even when a certain amount of proficiency has been acquired, the preference has been to return to scanning. It should be noted that some of these users can use the scanning when set at the maximum possible setting, and hence feel no need to increase speed by going to Morse.

ASSISTED KEYBOARD

The assisted keyboard mode, which allows a keyboard user to access shift, control and repeat functions with a single finger, has been used by residents who can use the keyboard but with only one hand. Typically, two flat switches are mounted on the left and right sides of a key guard, and are labelled for shift, control and the proper order for repeat.

EXPANDED KEYBOARD - MEMBRANE

The Expanded Keyboard mode is the one mode which promises some exciting creative development. It is possible to connect any array of switches up to an 8 x 16 grid, and have these switches redefined as a computer input of a desired character or characters. A commercially available membrane keyboard provides 128 one-inch light touch squares on a thin, flat surface. This surface can be overlayed with a visually meaningful display, making it meaningful according to the software program it is used with.

An example of this is for a Blissymbol display, which can be used with the Trace Center's Blissapple program. Touching one of the 128 squares can input to the computer the identifying number that corresponds to the Blissymbol on the overlay. The limitation to 128 symbols makes this appropriate only for elementary Bliss users, but this may be the group for whom number coding may be too difficult.

A popular application of the membrane keyboard at Bloorview is with a computer chess program. This program as it is written, requires a two-character code to be entered to identify the position of the piece. With an overlay of a chess board for the membrane keybord, and the AFC redefined to interpret the touched squares for the software program, chess can be played against the computer by touching the square of interest. For a user without the dexterity to manipulate physical chess pieces, it is possible to play chess in a more direct and natural way, and against an opponent who is sharp but also very patient.

Bloorview has also had success in constructing membrane-like keyboards with square sizes larger than one inch. Grouping adjacent squares on a standard membrane keyboard had been tried, but dead areas between squares was frustrating for users requiring this more gross arrangement. The larger squares are particularly useful for education programs for early concepts and cognitive processes. An example is The Learning Company's Juggles' Rainbow which can use four squares for above, below, left and right.

EXPANDED KEYBOARD - MULTIPLE SWITCHES

An adaptor recently developed at Bloorview allows connection of from 1 to 8 single switches, enabling each switch to input a predefined character or characters by means of the expanded keyboard mode. For example, the Spinnaker's Facemaker program requires only space and return to create a face. With this interface and a redefinition of two of the switch inputs, one switch inputs space, and the second inputs return, allowing someone with head control to use two lateral switches to use this program. Other redefinitions are possible using up to eight individual switches. This method has solved the problem of direct selection using multiple switches which do not use the hands.

LEISURE

The ability of the AFC to simulate joystick and game paddle operation with one or two switches has been well used at Bloorview, particularly with our adolescent age group. Space Invaders, PacMan, and Defender serve as age appropriate activities. In creating set-up programs for these games, especially with users unfamiliar with the detailed aspects of the AFC, making these games as "turn-key" as possible is important. A disk containing a number of games is created along with a menu, and a user can get information from the menu as to the type of game, the number of switches required, and the mode of play. Selecting a game then prepares the AFC by running a set-up program, and then loads the game automatically. This frees the user from having to specify AFC set-up paramaters which may not be understood.

CONCLUSION

The Adaptive Firmware Card has had a most significant impact at Bloorview in facilitating computer use for physically disabled individuals. Its flexibility in accommodating a variety of abilities and needs has been particularly important in an environment where a few computers have to serve a large number of users. Creative uses of the device continue to be explored as attempts are made to exploit the many adaptive possibilities.

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KEYBOARD EMULATION USING NRCC'S MOD KEYBOARD

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ABSTRACT - The MOD Keyboard allows a severely handicapped user to control a variety of computers. The many adaptations required for these computers have been implemented in the MOD keyboard in a manner which minimizes expense and complexity. This paper describes the MOD keyboard solution to keyboard interfacing.

RÉSUMÉ - Le clavier MOD permet à un utilisateur sérieusement handicapé de commander divers ordinateurs. Les nombreuses adaptations nécessaires pour ces ordinateurs ont été incorporées au clavier MOD tout en maintenant au minimum le coût et la complexité. Les auteurs décrivent les possibilités offertes par l'utilisation du clavier MOD comme interface.

The MOD Keyboard has been developed as a keyboard emulator device (1,2). This means that the MOD Keyboard replaces the keyboard of a target computer or terminal. It was designed as a vocational, educational and communiction aid for the severely handicapped. In the work place or school one meets a wide variety of computers. Unfortunately, each computer has a different keyboard requirement. There are four types of keyboard computer and terminal protocol, namely:

1. Serial encoded. 2. Parallel encoded.

3. Unencoded. 4. Other protocol.

In the encoded cases, encoding may be ASCII or some other code. The MOD Keyboard was designed to accommodate a wide variety of keyboard types. Presently it supports many computers with keyboard types 1-3. Type 4 is often found in terminal devices such as the VT100 (DEC) and the Visual 100 (Visual Technology

Material and Methods

To make connections between the MOD keyboard and a target computer, one or more output lines of the VIC-20 are required. Figure 1 indicates the standard input and output ports for the VIC-20 computer with the MOD Keyboard cartridge connected. These accessible ports and their use for the MOD Keyboard are:

1. Games I/O - Used as an input device for switches, analog joysticks and light pen. (2-A, 5-1/0)*

2. MOD I/O expansion - When the MOD cartridge is plugged into the VIC-20 memory expansion bus, a connector at the back of the cartridge allows external connections to a variety of devices. (2-I, 2-0, 16/0)*

3. Audio and Video - Used for connection to a monitor and loudspeaker.

4. Serial I/O - Used by the MOD for connection to some serial keyboards or the VIC-1525 graphics (1-I, 3 I/0)*

5. Cassette - Used for VIC-cassette connection (1-I, 2-I/0)*

6. VIC user port - used as parallel output connection for parallel keyboards and for connection to the VIC-1011A adapter for RS-232C connection. (Game port + 8 I/0, 1/I, 1-0)*

*(I - Input, 0 - Output, A - Analog)

MOD Keyboard adaptations for the variety of keyboards listed above is accomplished as follows.

Serial Keyboards

There is a wide variety of computers that use a serial connection between the computer and the keyboard. The type of serial protocol used in this serial link varies from machine to machine. Although ASCII encoded asynchronous transmission is often used, computers such as the IBM PC use special transmission sequences and encoded keys. For the IBM keyboard, connection is made through the serial I/0 port of the VIC-20. The MOD software converts the parallel ASCII data selected by the user into the appropriate signals for the IBM PC (4). Similar arrangements have been made for the Nelma Persona keyboard.

Parallel Keyboards

Interfaces for parallel output keyboards often use TTL levels (0-5 Volts) in their operation. Seven or eight bit ASCII encoding is prevalent among microcomputers. The keyboard interface provides at least one extra line that indicates to the computer when a key has been presssed. These provisions are easily made with the MOD Keyboard. Unfortunately, most parallel microcomputer keyboards also have special keys that are used for closing special purpose switches (e.g. reset for the Apple II Plus keyboard). Extra circuitry is required for this function. The MOD Keyboard presently supports the Apple II plus keyboard. The Apple IIe keyboard is supported by way of a special adapter card (6).

Unencoded Keyboards

Unencoded keyboards consist of switches connected in an array as well as a number of special switches connected separately. Several solutions have been proposed for this problem. The use of an EPROM as a method for converting parallel ASCII data into keyswitch closures (5) solves the problem for a number of keyboards. There are two notable computers that render EPROM usage impractical: the Commodore 64 and the VIC-20. An alternate approch is the use of crosspoint matrix switches (3). Although presently more expensive than the EPROM approach, the solution is universal. The MOD Keyboard has been used to control a VIC-20 keyboard using the crosspoint switches and the Commodore PET using the EPROM technique.

Other Keyboards

There are many other types of transmission protocols used in a variety of terminal keyboards. These range from single line bidirectional serial interfaces (VT100 series) to bidirectional paralle parallel interfaces. These keyboards require special circuity to produce the required signals. For these "problem" keyboards, the "streaming" approach via an RS-232 interface (2) obviates keyboard replacement. This prevents a user from changing any of the keyboard-alterable parameters of the terminal and using the Xon and Xoff protocols. Also, the streaming approach is not satisfactory for bisynchronous communication lines. For baud rates less than 1200, however, direct RS232C connection is adequate. We are approaching these keyboards on an as-needed basis.

Other Requirements

The MOD keyboard provides a keyboard display for selection of any one of the 128 characters of the standard ASCII character set. Many keyboards of computers and terminals have special function keys, generating functions and codes other than those of the standard character set. To accommodate these keys, the MOD Keyboard editor allows a user to program a word phrase file for use as these keys. The user can set up a word in the word phrase file such that when it is selected, the appropriate code is sent to the computer or terminal.

Conclusions

Many of the keyboards used by today's computers can now be replaced by the MOD Keyboard. Adaptations have been made for the IBM P.C., Commodore 64, VIC-20, Apple II plus, Apple IIe, Commodore PET, and the Nelma Persona. This covers a wide range of computers requiring serial, parallel or matrix interfaces. Other computers may be interfaced to the MOD keyboard by designing an appropriate connector, minimal external hardware and adding a simple software routine to the MOD keyboard operating system.

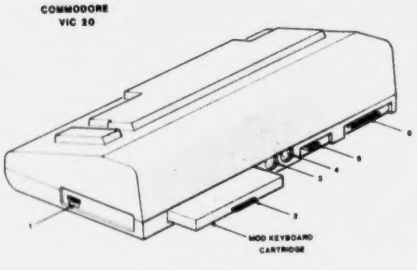

Figure 1. Diagram of the MOD keyboard indicating possible I/O connection points. (See text for explanation.)

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A SIMPLE SWITCH UTILIZING FRUSTRATED INTERNAL REFLECTION

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ABSTRACT - Frustrated internal reflection in clear plastic is used in a Morse code switch that can be gripped by the teeth and operated by the tongue tip. An "up-down-left-right-fire" tongue switch was developed for electronic games or a powered wheelchair control.

RÉSUMÉ - La réflexion interne inhibée dans un plastique transparent est utilisée dans un commutateur à signaux en morse qui peut être pris entre les dents et manipulé par le bout de la langue. Un commutateur lingual "en haut-en bas-à gauche-à droite-feu" a été mis au point pour les jeux électroniques ou la commande électrique d'un fauteuil roulant.

It has long been known[1] that light penetrates into a transparent material of lower refractive index when internally reflected, for angles of incidence exceeding a critical value. If another material is brought into contact with the internally reflecting surface a large fraction of the incident light will be transmitted and very little is reflected. This is known as "frustrated internal reflection", and the subject has been studied for more than a hundred years[2-4]. Very small mechanical motions can be detected and converted into electrical signals. Our first application of this principle was in a tongue switch for use by high lesion quadriplegics in emulating a computer keyboard with Morse code for word processing. Sip and puff switches were being used but they are expensive, difficult to sterilize, prone to frequent failure, and they limit the speed of sending code through the exertion required for continuous operation. A first switch was developed (Fig. 1 A) that internally reflected light emitted by an LED off the end of an acrylic bar back to a receptor mounted beside the sender. Two of these mounted together were used as a Morse code "bug", one for dots, and one for dashes. In a second design we were able to control two separate light beams in a larger bar (Fig. 1 B), and by sculpturing the end we were able to create a shape that was much easier to hold in the mouth so the contact surface for the tongue was behind the teeth, and the switching was generated as though one were speaking Morse code--"di di di dah". As the mouthpiece is a clear piece of plastic it can be easily removed for cleaning from the electronic package that is mounted a comfortable distance from the operator.

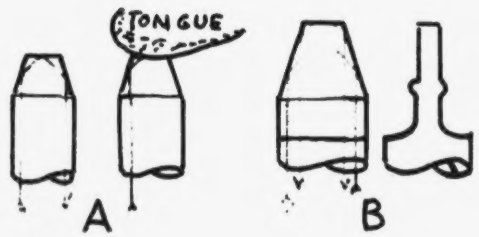

Figure 1

A final switch was built from 6 mm diameter rod and was successfully used with just one contact for Morse code. A slight modification in International Morse Code timing was necessary to allow a read-only memory chip to detect if the electric contact was meant to be a dot or a dash by the timing to the next signal. We refer to this as "Morris" code. The timing modification is so slight that operators trained in Morse can understand and receive "Morris" code. Morse code uses a unit of time for a dot or a space to the next code element. A dash is three units, as is a space between letters. A space to a new word is seven units. In "Morris"code we make the space to a new code element 1½ units, and the space between letters as 2½ units. This allows one to use the tip of the tongue for sending as in speaking--di di di dah, and requires only one make-break circuit.

An electronic game control switch has been built using the same principle. Five light paths were successfully incorporated in one acrylic rod (Fig. 2) in a cross pattern for up, down, left and right. The center "fire" position is slightly recessed to prevent accidental activation.

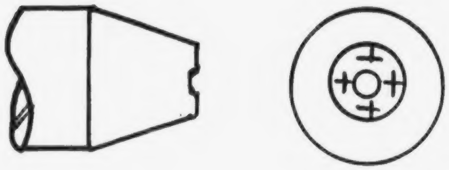

Figure 2

A suction pump for evacuating saliva from the mouth was fitted with a timer so when turned on it would run for 15 seconds. The evacuating tube is clear plastic fitted with an LED sender and receptor, and with the end bevelled at 22½°. The pump is activated for the pre-set time (15 seconds) when the tube contacts the inside of the mouth.

The studies of Goos and Hanchen[5] indicate that a small layer of a less dense transparent material will shield against external absorption, and this factor is extensively used in the fiber optics field. We fabricated a control switch to be actuated by the fingertip (or any other absorbing object, even the tongue) that has nine switches in a + form (Fig. 3) that was used for a two axis control for a wheelchair. The center switch is for "start" or "stop", and the "forward, reverse, left and right" are self evident. The inner direction controls are low speed and the outer are high speed. The contact surface is in effect "potted" and impervious to moisture or dirt. The potting material is transparent and of lower density.

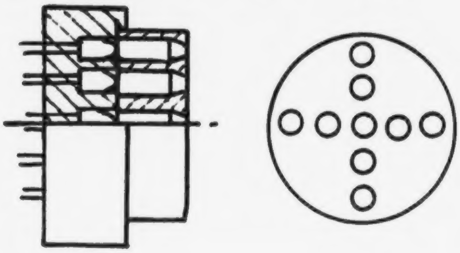

Figure 3

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THE TIMEX-SINCLAIR 1000 COMPUTER AS A VERSATILE LOW-COST COMMUNICATION AID

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ABSTRACT - This paper describes modifications made to the Time-Sinclair 1000 computer that allows it to be used as a communication aid for a physically disabled person who is also a non-reader. The modifications consist of an expanded keyboard with magnetic-field sensitive switches that is connected directly to the computer.

RÉSUMÉ - Les présentes recherches décrivent les modifications apportées à l'ordinateur Timex-Sinclair 1000 et qui en font un moyen de communication pour les handicapés qui ne peuvent lire. Les modifications consistent en un clavier muni de touches magnétiques et relie directement à l'ordinateur.

In recent years microcomputers have been adapted quite successfully for use as communication aids for persons with speech disabilities. At the present time, these devices, although useful, are often expensive. The decision was made to try to develop a device that would have only what was necessary, with no "frills," in an attempt to lower cost.

The Timex-Sinclair 1000 (TS) was selected as the computer to be adapted after comparing several computers that were under the arbitrary price ceiling of $100 (U.S.). The most important factors that were compared between these computers were not the computers themselves, but were the types of "peripherals" available for each computer, such as printers, speech synthesis boards, etc. Specifically, what was looked for with these peripherals was how they might be beneficial to someone who has disabilities.

After minimal expense and labor, this computer was adapted to make a very versatile communication aid. It was designed to meet the needs of those persons that have problems with producing speech, have difficulties with control of movement in their arms and hands and are also non-readers. The only modification to the computer itself was the soldering of several wires to the keyboard connections on the printed circuit board of the computer. The wiring itself was not difficult and this author, a person with minimal experience with electronics, was able to do the wiring without difficulty.

The second phase of development was the construction of a magnetic field sensitive keyboard. This keyboard was directly connected to the TS computer via the wires previously described through a connecting plug.

The keyboard was made by using a wooden lapboard from a wheelchair. On the bottom of this board was placed a wire-connected matrix of glass-cased magnetic reed switches. These switches respond to a weak magnetic field by closing and therefore switching to "ON." This matrix of switches was connected so that each magnetic reed switch would take the place of each of the 40 keys that are on the unaltered TS computer. The top of the wooden lapboard, with the matrix of switches underneath, was divided into 40 equal areas that are 2 inches square. One magnetic reed switch was placed under each one of these squares.

With this new keyboard, by moving small magnetic pointers around, input is made to the attached TS computer. With this adapted computer, any software developed for the TS computer can be run without modifications being necessary.

Two commercially available options for the TS computer itself were also purchased, a 16K RAM module (more memory), and a Sinclair printer. The total cost for all of the hardware, including a small screen television set and a cassette recorder, was about $250 (U.S.).

A simple computer program, written in BASIC, was developed to enable the computer to act as a message generator. Picture symbols were used on the expanded keyboard so that when the magnet-containing pointer comes near each picture on the large keyboard the appropriate symbol would appear on the TV screen. However, only the appropriate word or phrase that would go along with the picture would be printed by the Sinclair printer attached to the computer.

This modified computer system has been field-tested with several children that have disabilities of movement and speech production and who also are non-readers. These children have seemed to enjoy using this system, but the long-term benefits or detriments have yet to be determined.

An improved version of this system is currently being constructed which incorporates such features as speech output from a speech synthesis module (cost=$50 U.S) and an environmental control unit (cost=$200 U.S.) to remotely control lights, TV sets, or other electrical devices.

CONCLUSIONS: This project was the author's attempt to understand, at a practical level, some of what may be involved in the development of adapted computer equipment. While developing this device, it soon became obvious that the production of equipment that would be useful and available to a large number of persons with disabilities is a difficult task which should probably be done only by those that are appropriately skilled. However, it was also apparent that construction of such devices should not be attempted without closely studying the needs of people that are disabled and by examining how their unique abilities can be used to their best advantage.

TOWARDS CREATIVE USE OF MICROCOMPUTERS: A PROGRESS UPDATE

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ABSTRACT - This paper presents work carried out to date in the development of assessment procedures for prescribing microcomputer control systems for severely disabled persons, and in the demonstration of the functional and creative possibilities now afforded to these persons.

RÉSUMÉ - La présente communication porte sur le travail réalisé jusqu'à ce jour dans l'élaboration de méthodes d'évaluation en vue de proposer aux personnes gravement handicapées des systèmes de contrôle gérés par microordinateur et dans la démonstration des possibilités de fonctionnement et de créativité qui sont maintenant offertes à ces personnes.

INTRODUCTION

The Microcomputer Applications Programme at the OCCC has been involved in a research project examining issues of control of microcomputers by severely physically disabled persons. The first goal of developing a systematic assessment to prescribe the key factors pertinent to single-input control of the microcomputer has been achieved. (1.) Pilot work comparing three single-input selection strategies has also been completed. (2.) Work is presently underway to extend this development with the following goals:

(a) Develop principles and guidelines necessary to decide when to increase the number of inputs.
(b) Develop principles and guidelines required to choose the most appropriate selection strategy.
(c) Delineate issues regarding presentation of information for selection in order to increase efficiency.
(d) Examine the impact that providing control of a microcomputer and a creative outlet will have on a severely disabled person.

To provide a functional and creative environment for the subjects in the study, the programming language LOGO is being made accessible. LOGO is ideally suited for this pursuit since it stimulates creative learning through experimentation and self-experience (3.) and as greater numbers of LOGO commands are learned the need for better access to them increases.

This paper outlines the software developed to date, the controls and selection strategy assessments that are under development, and the experience gained in teaching LOGO to four severely disabled persons.

METHODOLOGY

Design : Assessment procedures will be developed to evaluate control of 1 to 5 input switches in conjunction with related information selection strategies. Comparisons of various systems will be objective and functionally oriented and to this end the subjects will be evaluated while using the computer language, LOGO, which they will be taught.

A front-end dual computer approach will be utilized; one computer will run LOGO and the other will run a specialized program that displays LOGO commands which can be selected with 1 to 5 inputs. Since some severely physically disabled persons may be unable to read traditional orthography, all LOGO commands will be available in the form of Blissymbols.(4.) Initially, the subjects will use a single-input control, and once proficient with LOGO, the number of inputs, selection strategy, and screen layout will be systematically altered to optimize input. An initial 3-month period has been allocated for the students to learn LOGO; each student's proficiency level at that time will be the level at which different accessing methods will be tested.

Subjects : Between October 1983 and June 1984, 4 subjects are participating. These subjects are all severely physically handicapped with cerebral palsy. A further four subjects, matched as closely as possible, are acting as a control group in order to explore possible differential effects of the LOGO experience.

Selection Strategies : At the time of preparing this paper, assessments for multiple-inputs and various selection strategies have not been finalized; although they will follow from our previous experience (1., 2.). For each number of inputs, up to three selection strategies will be assessed.

Front-end software : Four levels of front-end software have been developed in a series of increasing complexity. At the first level, LOGO commands have fixed distances and angles associated with them. In the second level, numbers from 0 to 3 are introduced, each number representing 10 LOGO units of direction or angle, or a LOGO colour. The third level (Figure 1) extends the numbers to 9. The fourth level provides control of the full capabilities of LOGO. Progression from one level to the next is determined by assessments that test knowledge of the system and physical access.

The front-end software allows quick rearrangement of commands and changes in scanning parameters. Inherent in all levels of the software is data collection. Daily session data recorded includes the screen arrangement; system scanning/input parameters; a frequency count of all commands used; lists of all commands used in specific tasks; and a daily record of instructor observations. Since a number of commands, such as "delete", were desired but not provided by LOGO, a number of LOGO procedures were written. These along with any games or tasks are loaded into the back-end computer.

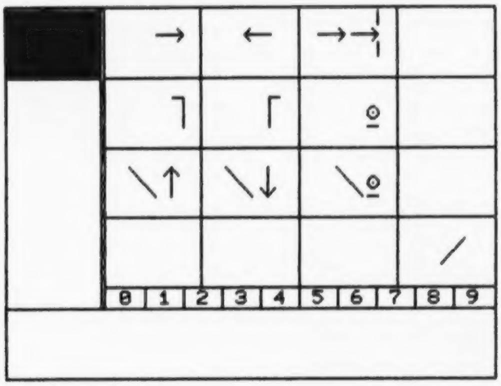

Figure 1 : Typical front-end display at level 3.

Implementation of LOGO : Our current practice is such that each student is seen in 4 one-hour sessions per week in their regular classroom setting. LOGO sessions have included both instructor-directed tasks and student-directed free-play. As the students had little previous experience in manipulative activities, concepts are presented in a systematic fashion to ensure that each building block is understood. Difficult concepts such as "left" and "right" turns are taught by demonstration first on the student, then with 3-D concrete objects, and finally with the more abstract 2-D screen "turtle". The instructor facilitates planning and problem-solving by asking leading questions and discussing different approaches to a problem.

RESULTS AND DISCUSSION

Results to date of the LOGO implementation have been particularly exciting and encouraging. In seven weeks of training, all four students reached level 3 and have begun to independently work out sequential steps required to create a drawing of their choice. In the past, passive participation in learning situations, was the only option available to these individuals. The success demonstrated is due to the overall combination of the front-end system; LOGO; a consistent and structured teaching approach; and initial intensive instructor/student interaction.

Specific areas of learning include control of the dual-computer system to make desired target selections, ability to plan steps to execute a given task, simple mathematical concepts without the use of mathematical terminology, and the ability to estimate distances and turns. The LOGO implementation has turned out to be a valuable diagnostic tool providing an insight into the student's cognitive style. An important discovery was that the students' difficulties often related to the verbal terms used rather than the basic concepts demonstrated. Thus, the instructor always verbalized the term with the implemented concept to reinforce association. Students' tolerances to work loads also appear to have increased. What was initially perceived by the students and the instructor as a lot of work is now being readily accomplished within the hourly session. It is interesting to note that the students initially perceived a task as being easy if they completed it, and hard if they did not. This may be related to their past experiences of failure, and their lack of recognition of the computer's ability to accommodate their weaknesses, i.e. saving unfinished work onto disk.

LOGO has in fact provided these students with a creative outlet as their drawings are evidence of abilities that only could be realized through the use of a microcomputer. Through even these initial accomplishments, these students who are often perceived as mentally retarded, have gained better self-images due to the new ability to independently work at an activity with prideful results for themselves, their parents, teachers and peers.

ACKNOWLEDGEMENTS : The authors gratefully acknowledge the generous support of the National Health Research and Development Programme, Health and Welfare Canada. Thanks are extended to Geb Verburg for input regarding research design; Sachi Tamura for her input on teaching LOGO; and Corinne Morris, Rabindra Nauth, Avinash Persaud, and Phil Olynyk for their programming support. The cooperation of staff and students of Sunnyview Public School and the Villa Private Hospital is also acknowledged.

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THE PHYSICALLY HANDICAPPED AND WORK-RELATED COMPUTING: TOWARDS INTERFACE INTELLIGENCE

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ABSTRACT - A project is described in which collaboration with a College of Further Education for the Disabled on the information processing problems faced by students is leading to the design of an experimental intelligent interface.

RÉSUMÉ - Il s'agit de la description d'un projet réalisé en collaboration avec un collège d'éducation supérieure pour les handicappés. Le projet s'intéresse aux problèmes de traitement d'information que rencontrent les étudiants, et permet d'élaborer l'expérimentation d'un interface intelligent.

The revolution in Information Technology is significantly advancing employment opportunities for physically handicapped people but, as computer-based tools become commonplace for carrying out information handling work, individuals who cannot use those tools well are likely to remain at an equally significant disadvantage.

The research described here aims to provide, at relatively low cost, productive and efficient access to application software for people whose disabilities make it difficult or impossible for them to use the conventional input methods employed by commercial software products. Our target is to find ways in which knowledge-based techniques can make the user/software interface more intelligent and thus reduce the physical demands made on handicapped users. The paper outlines the long-term research we propose in order to approach this target, but focusses on a description of an enabling project in which the authors are collaborating with a public College of Further Education for the disabled.

THE HEREWARD PROJECT

Recent funding from the Government's Department of Trade and Industry has enabled Hereward College, Coventry, to begin a two-year development to establish a centre specialising in the assessment of the communication and study needs of physically handicapped students before they enter further education. Particular attention is being paid to developments in Information Technology; each of the students entering the College in 1984 will be equipped with a modestly-priced Acorn BBC Model B microcomputer, disk drive and printer. Network facilities are also envisaged. Students will use the microcomputers for the production of 'written' work, and to gain awareness of the kinds of software they will need to master if they are to compete in the job market when they leave the College.

What we are aiming at in the collaboration can be seen from the model shown as Figure 1, which repeats the four function levels identified by Vanderheiden (1981) for microcomputer based systems in rehabilitation of handicapped individuals.

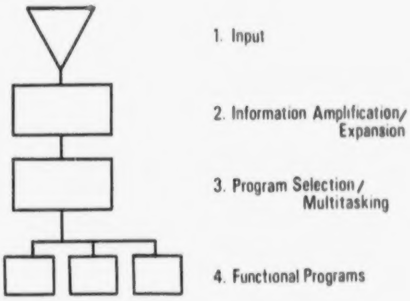
1. Input
2. Information Amplification/ Expansion
3. Program Selection/ Multitasking
4. Functional Programs

Figure 1 Function Levels

The first phase of the project is concentrating on levels 3 and 4. The project team identified the functions of word (text) processing, calculation facilities and graphics display as forming the basis for an 'electronic notepad' which would enable a student to execute efficiently a wide range of tasks and prepare good quality textual material.

Whatever the capabilities of each of the three functional modules, the evident need is to be able to move data and results from one to another with minimal user intervention, and for the user to select easily the program required as a point of entry. At the functional level it is planned to use a commercial spreadsheet program to provide general purpose calculation capability. It will be possible for a student to transfer results of calculations to and from the word processor and to display them graphically. It will also be possible to perform in-text real time evaluation of simple arithmetic expressions without leaving the word processor. Facilities for embedding graphics in the body of prepared text will be provided by a special purpose program already written at Hereward and by a commercial package. A selection system is being designed which offers a menu-based approach to using the 'electronic notepad'.

A later purpose of the project is to give access to commercial CP/M software, either by adding a recently announced Z80 processor board to the BBC microcomputers, or by networking the BBC machines to the College's Torch computer. The first application to be added will be database management, having clear links to the cluster of programs in the 'notepad'. The overall structure of the system is shown in Figure 2.

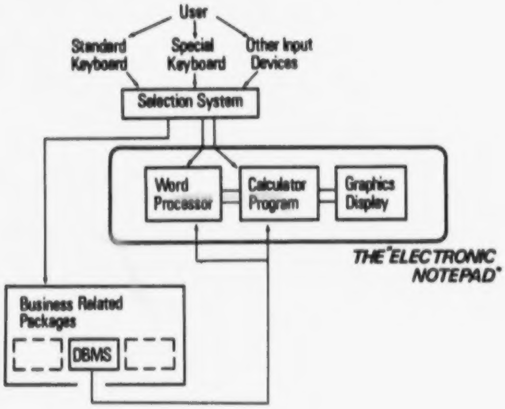

Figure 2 The Hereward System

In the early stages of the project, experimentation at the input level (level 1) is limited by shortage of funds, but two sorts of alternative input device are under evaluation. The first of these, the Concept Keyboard, consists of a rectangular plastic membrane covering a 16 x 8 matrix of touch pads: the second, the Microwriter, is a novel one-handed portable word-processor/data entry terminal. Both of these devices are readily interfaced to a BBC micro-computer.

ADDING SYSTEM INTELLIGENCE

Later stages of the project will be concerned with techniques of information amplification (level 2). There are several relatively inexpensive communication-aiding systems now available, some with scanning as a selection method (e.g. Possum Communicator), some using active direct selection techniques (e.g. Vocaid, MacApple). From the early systems, in which messages had to be composed character by character, have developed others which permit the user to choose from menus of words and simple pre-specified phrases. Almost all systems to date are, however, passive. The user is provided with sets of choices in a fairly static manner and the computer's role is simply to do the input/output handling, some storing of information and in some systems a certain amount of interpretation, for example the symbol-to-language translation needed in systems dealing with Bliss symbols. Developments in computer technology, and the contribution of Artificial Intelligence research to language understanding, now make it a realistic proposition to provide a system with knowledge and hence predictive capabilities in the preparation of messages and computer input: Rosen and Goodenough-Trepagnier (1982) survey current practice and prospects and draw attention to the problems of choosing an appropriate degree of prediction.

We plan to develop a prototype word processor which will take account of context and language redundancy within the text being composed. The levels of redundancy present in natural language range from orthography, through syntax and semantics to pragmatics and are increasingly expensive to compute, in the order given. Clearly, a powerful system will be required and at present such a system would not meet our requirement of affordability by most disabled individuals in the near future (say 3 - 5 years). Trends toward cheaper computing power suggest, however, that we should not rule out systems on the grounds that their size and power make them too expensive at present hardware prices.

The more advanced computer facilities at the University will be used in development of the prototype: it is likely to be tested at Hereward College on the promised 16-bit processor for BBC microcomputers.

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ADOPTION OF HOME COMPUTERS BY HANDICAPPED AND GENERAL POPULATIONS: A COMPARATIVE STUDY

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ABSTRACT - Home computer owners from general and handicapped populations are compared on individual and product attributes. A general consumer sample was obtained by Rogers, et. al., and a second from a national handicapped advocacy group. Limitations and implications are discussed.

RÉSUMÉ - On a fait une étude comparative des propriétaires d'ordinateurs domestiques (personnes handicapées et valides) en fonction de leurs caractéristiques individuelles et des caractéristiques de leur appareil. Roger et coll. ont préparé l'échantillon des usagers valides, le second échantillon ayant été tiré d'un groupe national représentant des handicapés. On discute les limites et les implications.

Consumers' preferences drive the development of home computers (HC's) in directions which may or may not be suitable for the needs of handicapped persons. Early-adopter attributes such as education, computer expertness, income, work and lifestyle affect the rate of diffusion. Product attributes such as relative advantage (the degree to which the innovation is perceived as better than the idea it supersedes), compatibility (the degree to which an innovation is perceived as consistent with existing values, past experiences, and needs of potential adopters), complexity (the degree to which an innovation is perceived as relatively difficult to understand and use), observability (the degree to which the attributes and results of an innovation are visible to others), and triability (the degree to which an innovation may be experimented with on a limited basis) also affect diffusion [1]. We compare general consumers who own HC's (GP) and owners who are interested in the needs of the handicapped (HP) on individual attributes and perceptions of product attributes.

Results of an early-adopter study at Stanford University with interviews of 77 HC owners [2] are used for the GP sample. Members of an organization of handicapped and non-handicapped persons interested in the computer needs of the handicapped constitute the HP sample. 249 questionnaires adapted from the Stanford survey were mailed, 105 returned, and 64 identified as HC owners. Selected chi-squared tests of independence of the two samples were performed. (We report the chi-squared, degrees of freedom, and p=largest confidence level.)

In the results, note that there is a sample bias in that both populations were convenience samples. However, comparison of age, size of family, income and educational level of the two populations does not support the notion of bias. Nevertheless, chi-squared statistics should be interpreted with caution. A response bias was noted in that interview respondents nominate answers while direct mail respondents select from a list, sometimes inflating the responses.

Individual Attributes. The GP and HP were very similar in educational experience. As highest formal education, 16% of the GP and 16% of the HP had some college, 25% of the GP and 28% of the HP had a BA/BS, 29% of the GP and 30% of the HP had a MA/MS and 28% of the GP and 23% of the HP had Ph.D or MD. The HP group was slightly older (mean age for HP=39, GP=36; chisq=11.5, df=3, p=.01). The mean personal income for the GP was approximately 35,000 and for the HP, 26,000.

A greater portion of the GP was made up of scientists and engineers (20% of GP and 6% of HP), business people (19% of GP and 11% of HP), and students (26% of GP and 9% of HP); whereas a greater portion of HP consisted of educators and rehabilitation personnel (27% of HP and 16% of GP) and unemployed (14% of HP and 1% of GP).

To assess the tendency to adopt technological innovations, both groups were given a list of eight recent personal-use, high-tech innovations and asked to indicate the ones they had adopted. The mean score for HP was 2.55 and for GP was 3.15.

Relative advantage. Immediate interest in owning a HC when they first heard about it was the same in both groups (53% of the HP and 59% of the GP were immediately interested). Brand choice decision factors were also alike for both groups. The bar chart in Figure 1 indicates the influence of these factors on brand choice: cost (1), software (2), programability (3), expandability (4), size and reputation of manufacturer (5), interfacing ability (6), and ability to link with others (7).

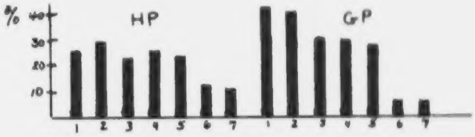

Figure 1: Influences on Brand Choice

The groups were similar in the number of days to get comfortable with the HC: mean for HP=36.78 days; for GP=36.04 days (these means do not include

6 of the HP and 4 of the GP who answered "not yet"). 69% of the HP and 71% of the GP found the HC to be time saving, but only 36% of the HP and 35% of the GP found it to be money saving.

The following table lists the major advantages and disadvantages expected prior to ownership and the portion of each group who listed each.

Advantages	HP	GP
Work-business	47%	29%
Personal accounts	17%	21%
Education	31%	2%
Word processing	56%	17%
Hobby/fun/games	28%	29%
Save time	19%	4%
Personal programming	27%	8%

Disadvantages	HP	GP
Cost	44%	61%
Hard to use/language	22%	17%
Fear of Obsolescence	38%	8%
Limited capability	6%	12%
Software problems	19%	12%

Compatibility. Expertise was gauged by the number of computer languages known, whether or not a computer was used at work, and computer journal readership. The two groups had approximately the same proportions of people who knew at least one computer language. The mean number of languages known by the HP was 2.09 and by the GP was 2.10. The GP had a significantly higher proportion of people who used a computer at work (81% of the GP and 56% of the HP; chisq=10.15 df=1 p=.0014). The HP, however, had a higher proportion who read computer journals (90% of the HP and 70% of the GP; chisq=8.734 df=1 p=.0031).

Complexity. The use most often reported by the HP was personal word processing (55%) with entertainment a close second (52%). A large portion also reported using the HC for work-related word processing (45%) and as a learning aid (45%). A bar chart is given in Figure 2 indicating the mean use time weekly for each group for these HC functions: entertainment (1), personal (2) and work-related (3) word processing, budgeting (4), learning aid for children (5), learning aid for self (6), business management (7), and database access (8).

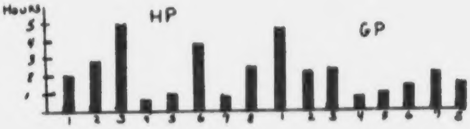

Figure 2: Mean Use Time, Weekly

75% of the HP and 62% of the GP (chisq=13.02, df=1, p=.0003) reported problems with the HC. The problems most often reported were unclear written instructions (37% of GP and 53% of HP who reported any problem reported this), difficulties learning to use the system (35.5% of GP and 51% of HP), and breakdowns (40% of GP and 44% of HP).

Observability. The GP reported knowing an average of 4.5 HC owners prior to purchase and the HP reported knowing an average of 5.6 HC owners. The most often reported advantage to the HP was text processing (48%) and to the GP was entertainment (36%). The main disadvantages told to GP were software problems (39%). The main disadvantages told to HP were cost (49%) and software problems (42%).

Three methods of communication are considered: verbal, demonstration, and persuasion. The number of persons the owner talked to about his HC is verbal communication (mean for GP=12.5; for HP=19.8). The number of persons the owner showed the HC to is demonstrated information (mean for GP=4.81; for HP=4.89). The number of persons the HC owner encouraged to buy a computer is persuasion (mean for GP=8.22; for HP=15.7). Some of the counselors and educators of the HP group reported opportunities to talk to large groups of people about HC's. The content of messages between owners and prospective owners are more positive than negative for the GP. This was not evident with the HP (2:1 for GP; 1:1 for HP).

Triability. Owners were asked if they had an opportunity to try out a HC before they purchased it. 66% of the GP and 58% of the HP said they had.

Conclusions. The two populations were very similar in educational level and age but differed on occupational configuration and income. The GP had more high-tech and business personnel, while the HP had more educators/rehabilitation workers and unemployed. The product attribute of triability was very similiar for both groups. The expertness of the two groups was also considered similiar, with GP having access to their expertise from work-related activities while the HP got theirs from computer publications. More of the HP experienced problems, but the problems did not differ from those of the GP. The perceived negative aspects and the negative aspects reported to prospective buyers in both groups do not match; yet, the positive aspects do.

The diffusion of the home computer to the handicapped population will be inhibited by lack of income and by early adopters experiencing problems without having access to expertise. The GP does not consider the HC a tool in quite the same way as the HP and is able to draw more on work environment.

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THE MICROCOMPUTER AS AN "ORTHOTIC" DEVICE FOR COGNITIVE DISORDERS

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ABSTRACT - A computerized "Cognition Orthosis" is being developed to augment the capabilities of brain injured individuals and increase their independence. The Cognition Orthosis consists of a special programming language (COGORTH) and programs (written in COGORTH) to guide patients through sequential tasks. An example from clinical trials is presented.

RÉSUMÉ - Une "orthèse de cognition" informatisée est mise au point pour augmenter les capacités des personnes blessées au cerveau et accroître leur autonomie. Elle consiste en un langage de programmation spécial (COGORTH) et des programmes (écrits en COGORTH) visant à guider les patients dans des tâches séquentielles. Un exemple tiré d'expériences médicales est présenté.

INTRODUCTION

The microcomputer offers a dynamic medium for the presentation of tasks requiring perceptual skills, memory, attention and complex problem solving. In recent years, a number of computer programs for cognitive retraining of brain injured individuals have been introduced (1-4). These applications of microcomputer technology have been based upon the reasonable belief that at least some cognitive limitations of brain injured patients are retrainable. However, many cognitive deficits may not be fully remediable, even after considerable periods of time. No efforts have been reported towards the development of compensatory microcomputer systems for augmenting cognition in patients with limitations that are unresponsive to remedial efforts.

A computerized "Cognition Orthosis" is being developed to address the rehabilitation needs of patients who no longer respond to the drills and practice exercises of remediation programs. The Cognition Orthosis is intended to augment the cognitive capabilities of brain injured individuals and increase their independence.

COMPUTER METHODS

There are presently two components to the Cognition Orthosis: A programming language ("COGORTH") with an associated programming language interpreter (COGORTH interpreter); and Instructional Modules (IM's).

The COGORTH Language and Interpreter.

COGORTH (COGnition ORTHosis) is a programming language for the Apple II personal computer which provides a highly structured environment for efficient development of Instructional Modules (COGORTH programs) described below. The COGORTH interpreter executes programs written in COGORTH. COGORTH permits the programming of sequential messages (with extensive branching capabilities) that are displayed on a video screen and used to guide patients in the completion of complex activities. It has provisions for checking a patient's performance for errors; branching to error correcting procedures; timing each stage; managing interruptions of a task when a higher priority task must be completed; using audio and visual cues (environmental control) to request a patient's attention at the computer display; and permitting communication with other individuals who may wish to be notified of a patient's compliance with an activity program. A COGORTH program can display directions to the patient at any level of specificity, for any task which can be divided into discrete steps.

Instructional Modules (IM's).

IM's are COGORTH programs which guide patients through various activities. IM's contain lists of visual and auditory messages which are presented to a patient in sequential order. When well designed, IM's allow for recognition of a wide range of patient errors and provide instructions for error correction. IM's can be programmed to display message sequences at specified times, interrupt one message sequence with another of greater priority (as specified in the IM), and assist a patient who is experiencing difficulty returning to a task which has been interrupted by some other event.

CLINICAL TRIALS

An example from clinical trials is described to illustrate the efficacy of the Cognition Orthosis. The patient was a 28 year old woman with a wide range of neurocognitive deficits (including severe memory impairments) associated with an episode of herpes encephalitis. Preliminary investigations using the Cognition Orthosis for "artificial tasks" were first performed to evaluate its use with the patient. A task was then chosen which the patient might expect to perform at home. The patient was required to do the following:

1) Using the directions on a box of cookie mix, prepare batter for two batches of cookies;
2) Place the first batch of cookies in the oven;
3) While keeping track of the time required for cooking (8-10 minutes), prepare icing to be placed on the cookies when done;
4) Take the cookies out at the appropriate time.

All sessions with the patient were videotaped for evaluation. During initial trials the patient was instructed to complete these tasks using only written instructions and no assistance from other persons. As anticipated, the patient made many errors during these sessions including not accurately following directions on the cookie mix box, becoming confused about which recipe on the box to follow, and allowing the cookies to burn.

During the second phase of the project, IM's were written which provided her with instructions for performing the same tasks. The patient was able to perform the cookie baking task with *no errors* while following the step by step *instructions* presented by the computer.

Finally, a single trial was run in which the patient was once again instructed to complete the cookie baking task with only written instructions. Many of the same errors made during phase one were repeated during this phase.

DISCUSSION

Tools and techniques such as the Cognition Orthosis are a potentially significant component of rehabilitation programs for brain injured patients (with residual cognitive limitations) for the following reasons:

1) A computerized Cognition Orthosis is a *compensatory* rather than a *remedial* tool. *As such it addresses the needs of patients* who are not improving with the drills and practice exercises so typical of remedially oriented, cognitive retraining programs.
2) A Cognition Orthosis can potentially reduce the cost of caring for brain injured patients by increasing the range of activities they perform without human supervision.
3) Because the microcomputer creates a consistent, structured, programmable, and highly interactive environment, it can have indirect therapeutic benefits for patients such as the moderation of confusion, anxiety, self-disparagement and helpless feelings. The term "engineering therapy" has been used to represent such benefits secondary to the immediate goals of technological intervention (5).
4) The Cognition Orthosis itself may prove a useful tool for remediation.

Results with the computerized Cognition Orthosis have shown that it can be used to compensate for cognition deficits in daily living activities. Further research is now needed to determine the range of cognitive deficits amenable to this type of approach and the extent of its capabilities to make up for these deficits.

ACKNOWLEDGEMENT

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ADDRESS

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COMPUTER AIDS AND DIAGNOSTICS

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ABSTRACT - There are many computer-based aids being developed for a variety of users. One often overlooked but essential part of these aids is the built-in facility for diagnostics. The reason for and the types of diagnostics for use in aids are discussed.

RÉSUMÉ - De nombreuses aides informatiques sont mises au point à l'intention d'une variété d'utilisateurs. Un aspect souvent négligé mais essentiel de ces aides est l'option intégrée pour diagnostics. On traite des raisons qui ont conduit à l'élaboration de ces aides et des types de diagnostics qu'elles permettent.

Background

Research and development in the area of computer-controlled aids for the handicapped is fast and furious. In order to expedite projects, development of new aids is often made at the expense of good engineering practice. One item that is often neglected along the way is diagnostics. Diagnostics are software routines used to test the operation of a device. They are executed either every time power is applied to the computer aid or at the user's request.

Regularly used in manufacturing of microcomputer based products (2), power-on diagnostics provide the following advantages:

1. Reduce the amount of manufacturing functional testing.

2. Simplify field testing (purchaser testing).

3. Lessen customer confusion.

In the aids for the handicapped area, reducing customer confusion is the most important issue. A person buys an aid to minimize the amount of hardship affecting his living or working activities. Since the user is not normally familiar with the aid's internal workings, there may be much confusion if the device does fail.

Many newly developed computer-based aids use EPROM (Erasesble, Programmable, Read-Only, Memory) to house the program that operated the aid. There is a chance that some area of the EPROM was not programmed properly. Failure of a single bit may cause the aid not to work at all or to produce peculiar results under some circumstances. The latter case proves to be the most perplexing for a handicapped user, who upon seeing his error immediately perceives it to be caused by the own handicap or lack of knowledge about the aid. Aids must be designed so as to simplify operation and maximize reliability. A well implemented set of power-on diagnostic routines bolsters the aid's reliability as well as the user's confidence in himself and the aid.

Method

The diagnostic routines of a computer-based aid must be the first routines executed in the power-on sequence of the aid. Adding these diagnostics requires some software and perhaps some hardware to make the package almost totally tested every time the power is turned on. Tests that are performed include:

1. Microprocessor instruction set,
2. EPROM checksum test,
3. RAM test,
4. Display test,
5. I/O check and
6 Battery check.

Thest tests are quite simple to perform but offer an effective way to ensure correct aid operation before the user stumbles over an error.

Using the system of Figure 1, implementation of these tests is indicated below.

1. Instruction set. Before any other test is performed, some very simple arithmetic and decision operations are performed to ensure microprocessor integrity.

2. EPROM checksum test. The EPROM contains the operating system for the aid. A simple way of testing its integrity is a checksum test. Two bytes of the EPROM contain the result of adding together all the other bytes of the EPROM. This result is called a checksum. In the checksum test, the checksum is calculated and tested against the one stored in the EPROM.

3. RAM check. After the instruction test is completed, a simple RAM test is performed. Any RAM to be used by the test program itself is

RAM to be used by the test program itself is tested first. Then the rest of RAM is written with a pattern that tests for bit errors and address conflicts (2). All addresses are written first then read later. Battery-backed RAM may be tested by saving its contents in a pretested area of volatile RAM, then performing the test and finally restoring the data upon completion. The problem with this technique is that there is the possibility of someone turning off the aid while this test is being performed, resulting in some part of the RAM being altered. This problem is corrected by using a power supply monitor that generates an interrupt when the power supply drops. The data to be saved in battery backed RAM is restored if the microprocessor was in the midst of a test.

4. Display test. If a light emitting diode or a liquid crystal display is used, all elements of the display may be turned on at once for 1 second. This indicates the display's integrity. Video displays are tested by writing a pattern on the screen.

5. I/O check. Indeally any input or output line will have some provision in the system hardware to allow interconnection of input to output lines for automatic testing. Without this hardware, the interface adapters used in the aid are tested by reading from and writing to their various registers.

6. Battery check. This test is especially important for battery-backed RAM. The aid's hardware provides a way for the microcomputer to sense whether the battery voltage is above an acceptable level. A message on the display device indicates to the user the presence of a low battery level.

For tests 1-5, if an error occurs, the problem is indicated on the display device by a message or an error number. The aid then becomes locked in the error mode, making repair necessary before any further operation.

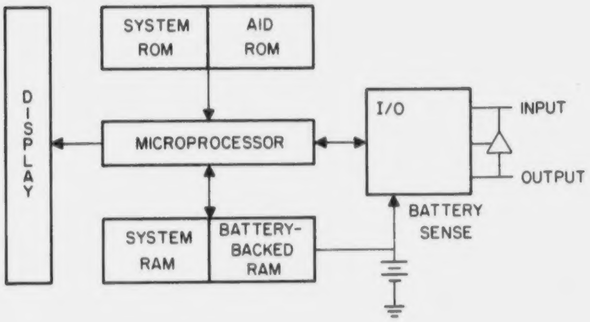

Figure. 1 Block diagram of a typical aid.

Conclusion

With technical aids becoming more complex, and with more people relying on them, it is essential to ensure their correct operation. Diagnostic testing is an effective way of providing a user with a simple but friendly way of informing him of a problem. Not only does it give the user more confidence in the product and himself but it also helps the manufacturer correct any problems that may appear. Many of the tests mentioned here have been implemented in later versions of the MOD keyboard (3).

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SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 7

PROSTHETICS AND ORTHOTICS II - EVALUATION AND FABRICATION/

PROTHÈSES ET ORTHÈSES II - ÉVALUATION ET FABRICATION

OMNI DIRECTIONAL HEAD SUPPORT SYSTEM

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ABSTRACT - A four-year old high level C1-2 quadriplegic secondary to a motor vehicle accident, required a head support system. The system eliminates occlusion of the trachea, increases head stability especially important during transportation, and can be used to develop increased muscle tone.

RÉSUMÉ - Un enfant de quatre ans souffrant de quadriplégie de niveau élevé C1-2 par suite d'un accident de la route avait besoin d'un système de maintien de la tête. Ce système élimine l'occlusion de la trachée, augmente la stabilité de la tête, particulièrement importante au cours des déplacements, et peut être utilisé pour augmenter le tonus musculaire.

Introduction

The patient, a four-year old male, has traumatic quadriplegia with high spinal cord lesion, resulting in very limited head control only. He was fitted to a wheelchair with a life support system, modular seating, tray and headrest. (Figure A.)

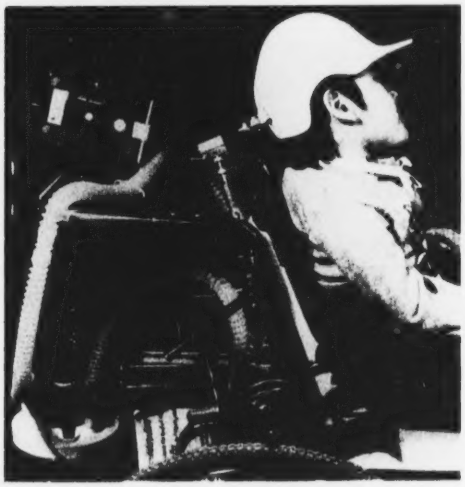

Figure A.

The foam headrest worked initially, but as he was trying to use his limited head control, he frequently ended up with his head in flexion and was unable to bring it to the normal position. This caused occlusion of the trachea and his inability to breathe. Lateral movement was very limited with one side being slightly better than the other. The patient was confined to a wheelchair from morning to night, except when lying down, and received twenty-four hour nursing care.

Because of time constraints, a basic head support system was fabricated which consisted of a helmet and a spring loaded flail arm hinge that gave minimal lateral movement, but allowed for flexion, bringing the head back to the normal position, due to the spring tension.

The system was functional but inadequate and it was felt that an omni directional support system was required. The system

(a) would give a complete range of head motion
(b) stop any undesirable motion
(c) increase head stability, especially during transportation
(d) be interchangeable with the foam headrest
(e) restrict head motion in any given direction yet be adjustable in any direction to facilitate neck muscle strength and improve muscle tone.

Design

The A.B.S. plastic helmet consists of a baseball cap style fabricated over a mould of the patient's head. (Figure B.)

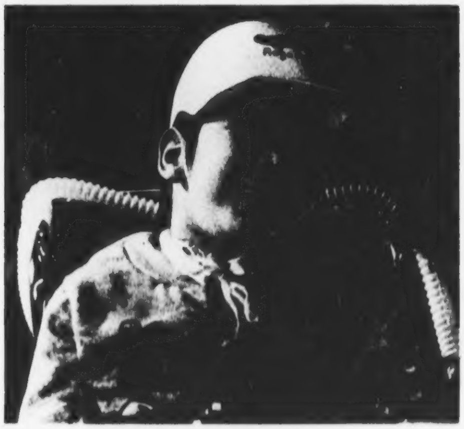

Figure B.

The cap was lined with one-quarter inch aliplast for comfort. To the helmet an omni directional head support was fabricated and securely attached (Figure C.)

Figure C.

The head support was fabricated from aluminum and consists of four adjustment settings and two moveable springs for flexion control. (Figure D.)

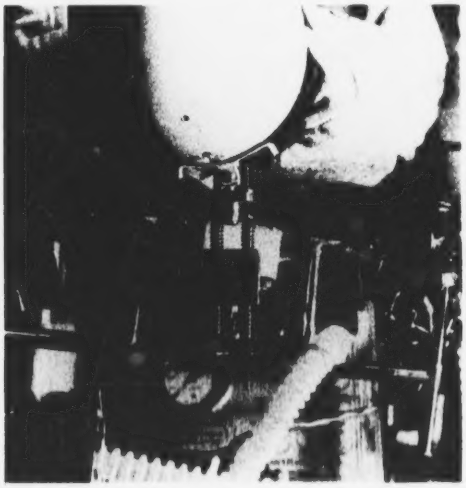

Figure D.

The head support was attached to the wheelchair insert via a normal headrest attachment mechanism. The omni directional device was constructed to allow adjustable side-to-side rotation, lateral flexion, and spring loaded extension and forward flexion.

Conclusion

These muli-adjustable ranges of freedom have allowed the patient to be less dependent on others in keeping his head stable over his shoulders, yet allowing him head mobility within his limits. We feel that this device has satisfied the goals that we set up for this patient. We anticipate it to serve as a theurapeutic device to strengthen head control muscles, as well reinforce tolerable ranges of motion.

A DESK-CHAIR MODIFICATION TO RELIEVE AXIAL LOADING OF THE SPINE

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ABSTRACT - Severe back pain is a major problem associated with bony spine damage. This pain is often aggravated in any position which increases axial loading of the spine. We describe a practical seating arrangement that reduces spinal loading.

RÉSUMÉ - Des douleurs intenses au dos sont une séquelle importante des dommages aux vertèbres. Ces douleurs sont souvent accrues dans des positions qui augmentent la charge axiale de la colonne vertébrale. Nous décrivons une position assise pratique qui réduit la charge imposée à la colonne vertébrale.

Biomechanics

A simple biomechanical model of the axial forces (Fa) at an intervertebral disc of a seated person is shown in figure 1. It is assumed that the point of rotation for spinal flexion is at the disk (Point P). Upper body mass (W) is centered at length L1 from P. The force (F1) generated by the extensor muscles of the spine, acts at a distance L2 from P. Equilibrium equations are as follows:

$$F1 = W \times (L1/L2)$$
$$Fa = F1 + W$$

As the individual leans forward, the ratio L1/L2 increases; therefore, Fa increases as well. Studies have shown that in a normal seated position, the axial force at the L3-4 level is approximately 250% of the total body weight (1). It is hypothesized that in many cases, the degree of pain in individuals with spinal damage is related to the force Fa.

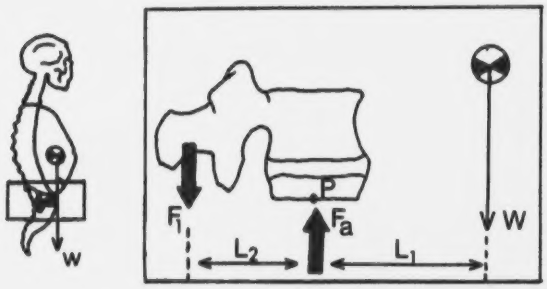

Figure 1 (adapted from ref. 1, pg. 41)

Static Equilibrium equations show that the Force Fa can be reduced by providing a vertical upward-acting force (F2) anterior to the vertebral body (Figure 2) or by a horizontal posteriorly-directed force (F3) above the lumbar vertebrae (Figure 3).

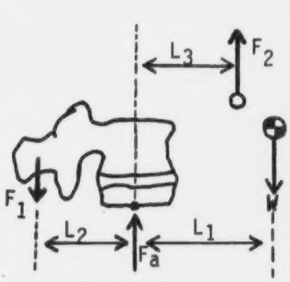

Figure 2

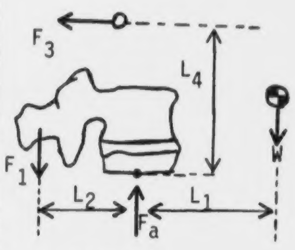

Figure 3

Case History

O.C. is a 63 year old female who was in good health until 1977 when a left breast mass was diagnosed as scirrhous carcinoma, a radical mastectomy was performed and she was begun on chemotherapy. In 1978, a right simple mastectomy was performed. In 1981 she developed midline back pain at the thoracolumbar junction. Metastatic breast carcinoma to the T12-L1 vertebrae was diagnosed on the basis of radiographic studies and bone scans. From 1981 to 1983 she was treated with local irradiation and chemotherapy. During this period, the spinal metastatic disease progressed minimally, but her back pain progressed to the point that her sitting and standing tolerance was limited to 10 to 15 minutes. The pain was clearly exacerbated by positions producing axial loading of the bony spine and was ameliorated by postions which offloaded the spine. Other than her position related back pain, she felt relatively well.

The patient was a self-employed Silversmith with an intense desire to renew her vocational activities. She had become unable to work secondary to the back pain. Her work environment included three separate benches arranged in a U-shape with an easily adjustable height swivel chair in the middle. The patient had tried a variety of temporary measures to relieve the discomfort, but nothing was adequate. Several ideas were proposed and discussed; the results presented were provided for her.

Design

The design criteria for this project are:

1. Apply the biomechanic principles mentioned previously to minimize the axial forces on the thoracolumbar spine. This was to be done by applying both constant and position related forces to the patients body.

2. The forces applied to the users body must be distributed evenly for comfort.

3. The client must remain mobile in the chair. Being a craftsperson, she must have free use of her hands. She must also be able to lean over and pick things up from the floor.

4. Use of the client's height-adjustable chair is preferred.

5. Other factors such as aesthetics, cost, and size of the modification must be considered.

The final design is shown in figure 4. A water-ski vest (A) is worn by the user. The back of the vest is stiffened with plastic and a D-ring attached to fasten a rope (B). This water-ski vest is fully padded with 0.5 inch high density foam and is easily slipped on and removed with three fasteners on the front. A 5 x 2.5 x 0.125 inch aluminum channel (C) is fastened to the chair back support. A rope (D) is strung from the vest over a pulley (E) at the top of the channel to a nylon bag of sand (F). This bag of sand applies a constant force to the client's upper back . A 0.25-inch elastic cord (G) is strung from the nylon bag of sand down around two pullies (H) at the bottom and then back up the side of the aluminum channel. It is then cleated at the top (I). The elastic strap provides an additional variable force which the user can easily adjust when seated. The external pulling force on the client is therefore

$F3 = Ws + KX$

where Ws = Weight of Sand
K = Elastic Cord Spring Constant
X = Elastic Cord Extension

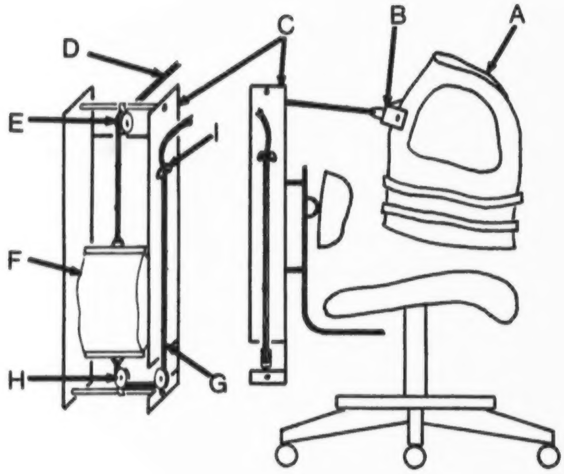

Figure 4

Results

Approximately 8 lbs of force is required with the client seated in an upright position. This includes a 6 lb. weight (Ws) plus a 2 lb. initial tension in the elastic cord (KX). The client is able to adjust the elastic cord tension for comfort in whichever position she works. During use, the vest has tended to "ride up" on the client and interferes with her work. The shoulder strap was therefore removed.

The most significant result of this work is that it has proved successful enabling the client to increase her sitting tolerance from 10 minutes to 3-4 hours per session. The client is now working on a daily basis at a level sufficient to sustain her silversmith's business.

Discussion

The problems associated with back pain aggravated by axial loading of the spine can be significant. This phenomenon is seen in patients with damage to the bony spine, with pure intervertebral disc disease, and with other etiologies. While the severity of many of these cases does not justify the aggressive approach taken here, appropriate treatment of severe, prolonged back pain may postpone or prevent the extreme disability often seen when sitting and/or standing tolerance is markedly reduced. A simple chair modification that minimizes the problem of reduced sitting tolerance associated with back pain produced by axial loading of the spine has been described. It is believed that this same approach may be applicable to a number of people whose pain is produced by the mechanisms discussed.

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THE DEVELOPMENT OF A NEW CERVICAL SPINE ORTHOSIS - THE CANADIAN COLLAR

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ABSTRACT - This paper describes a new cervical collar that has been developed for the management of arthritis. The collar is readily adjustable, cooler and more supportive than conventional collars. A wide range of additional disabilities can be accommodated. This collar is an example of the new family of Tubular Orthoses developed by the MERU group.

RÉSUMÉ - Cette communication décrit un nouveau collier cervical qui a été mis au point pour le soulagement de l'arthrite. Ce collier est facile à régler, moins chaud et plus ferme que les colliers conventionnels. Une gamme étendue de handicaps divers peut être ainsi soulagée. Ce collier est un exemple de la nouvelle famille des orthèses tubulaires mise au point par l'équipe MERU.

INTRODUCTION

Experience with arthritis patients has made clear the need for a new cervical collar for the management of rheumatoid and osteoarthritis. Complaints of heat by patients and concern for the lack of firm resistance against flexion were considered to be major failings of soft or plastazote collars. The prime requirements were improved support and reduced heat retention but other factors, such as light weight, ease of adjustment and reasonable cost and cosmesis were also apparent. Some of these subjective findings have been supported by radiological evaluations of various cervical orthoses (1). Functional, cosmetic and cost restraints usually preclude the use of the more rigid types of collars in the management of arthritis. A new family of orthoses, Tubular Orthoses (2), is under development by the Medical Engineering Resource Unit. These orthoses utilize tubing and clip-together components which result in orthoses that are cooler, lighter and more adjustable than most orthoses, and provide good support without unnecessarily inhibiting function. This approach has been used in the construction of the Canadian Collar. (Figure I)

STRUCTURE AND ASSEMBLY

The basic structure of the collar is two pieces of pliable, clear P.V.C. tubing which form the upper and lower perimeters of the collar. Six short nylon tubes, which provide the vertical support, are connected to the p.v.c. tubing by 'T' junctions. Anterior support is maintained by preformed nylon rod chin and breastplate pieces and by a small chin cup. Custom fitting is achieved by selecting the appropriate length nylon tubes and cutting the P.V.C. tubes to length. Three pairs of nylon tubes are symmetrically arranged each anteriorly, laterally and posteriorly. They are selected from precut tubes, facilitating rapid assembly and adjustment of the orthosis. The nylon rod for the chin support and the breastplate ring are inserted into the anterior support tubes, which also provide a means of securing and removal of the collar. Assembly and fitting takes 30-45 minutes.

Figure I

Figure II

PRELIMINARY CLINICAL TRIALS AND RESULTS

The objective of the preliminary clinical trials was to determine whether this new collar would gain acceptance by the patient, therapist, orthotist and physician. 20 collars were fitted, primarily to arthritis patients, but also to patients with cerebral vascular accident, amytrophic lateral sclerosis, osteomyolitis, whiplash injury and spinal cord injury. The mean age of the trial group was 53 years (range 4.5 to 79 yrs.), 13 were female and 7 were male. The orthosis was classified as a success if used on a regular basis, and considered to give pain relief and improved stability.

Fifteen of the patients fitted were considered as successful subjects, 3 were partial successes and 2 were classified as failures. These 2 patients found the collar uncomfortable, restricting and offering no pain relief. The patients classified as partial successes had compounded problems and/or poor motivation such as severe rheumatoid arthritis flareups or inadequate appreciation of the importance of head support.

Patients that considered the collar a success cited coolness and good support as being important advantages over the soft or plastazote collars. Frequently pain relief was mentioned along with an enhanced ability to communicate, watch T.V., type, write and read. Selection of neck flexion angle when fitting the collar markedly influenced function in these areas. Only two patients were unable to put the collar on themselves. These patients both had severe rheumatoid arthritis with resulting poor hand function and this may have contributed to the only partial success of the collar in these cases. Duration of daily use of the collar varied from occasional use for specific tasks to almost continous use during waking hours. A soft collar was frequently prescribed for night use. Asymmetrical disabilities were accommodated in a number of cases and the patient shown in Figure II is the most asymmetrical patient encountered to date.

Another example of a difficult to fit patient is shown in Figure III. This patient had severe flexion contracture due to secondary metasteses of the cervical spine and was occluding his tracheal tube due to this posture. The collar was able to maintain the depicted posture while permitting access to the tracheal tube for suctioning.

Figure III

DISCUSSION

The new collar has gained ready acceptance by patients, therapists and orthotists, and it is now being prescribed by physicians. The prime area of application appears to be the management of rheumatoid and osteo-arthritis. Its functions for this disability are the relief of soft tissue strain due to ligamentous laxity; and protection against excessive movement of the atlanto-axial joint, reducing the risk of nerve compression. Cosmetic considerations are met, as the collar can be partially hidden by clothing and hair. The front fastening facilitates use by most patients with multi-joint involvement and the adjustability allows for fine tuning of the amount of support given. Reduced heat retention and increased support are the major advantages of the collar over conventional types commonly used in arthritis.

Spinal cord injuries are potentially an important area of application, where the functions of protection and stabilization are of prime importance. The collar accommodates a tracheal respirator tube and two high level quadraplegics have been fitted with this collar. One is shown in Figure IV.

Figure IV

Posture control in disabilities such as A.L.S., multiple sclerosis and head injuries resulting in flaccid neck musculature have been managed by the new collar. A pilot study on ten patients with multiple sclerosis is now being conducted and the results will be reported. Use in emergency care, transportation and whiplash injuries is also being considered, as a replacement for the standard issue soft collar. One whiplash case has been encountered to date and she was the only patient to require an occipital pad.

Current plans for the collar include refinement of design, radiological determination of the amount of cervical spine immobilization offered and expansion of use to other disabilities. Design improvements could be made to the chinpiece in order to control rotation. An extension resist has been provided to three patients and this, together with lateral flexion resists, will be evaluated. Clear plastic 'T' junctions and tubes are being considered to further improve the cosmesis. Commercial availability is established.

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A TRACTION BOW FOR UNINTERRUPTED APPLICATION IN SPINE DISORDERS

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ABSTRACT - A portable traction bow with continuously adjustable elastic tension was designed and tested for applications requiring skin or skeletal spinal traction. Using a fiberglass tubular structure with elastic cord and ratchet drive the instrument can maintain distraction force uninterrupted through patient transport, in-bed positioning and treatment and through radiologic examination until surgery.

RÉSUMÉ - Un cadre de traction portatif à tension élastique continument réglable a été conçu et éprouvé pour des applications nécessitant une traction de la peau ou de la colonne vertébrale. Il est composé de tubes de fibre de verre, d'un câble élastique et d'un treuil à rochet. L'appareil peut entretenir une force de traction continuelle pendant le transport, le positionnement sur un lit et le traitement d'un patient ainsi que pendant l'examen radiologique jusqu'à la chirurgie.

Introduction - The use of traction in the management of spine disorders requires good clinical and radiographic evaluation. Traction may be obtained by applying a halter around the head and the pelvis for skin traction or pins to the skull and femurs for skeletal traction. In either technique a rope passes from the appliance on the body over a pulley, to a hanging weight which applies the traction force. Using hanging weights for the application of spinal traction is an acceptable and common method of treatment for scoliosis, fracture or fracture dislocation of the spine. Skin traction is often used in lumbar disk protrusion or cervical spondylosis treatment. For more severe cases in acute or sub-acute fracture dislocation of the thoraco-lumbar spine halo-femoral skeletal traction is necessary.

Free hanging weights, external to the bed require extra space and are uncomfortable to the patient from sudden motion of the weight, relative to the bed. Hanging weights also interfere with patient transport and demand interruption of traction for radiologic diagnosis such as myelogram and the computerized axial tomogram. Thus, an added risk to the spine is introduced and the cord may be further compromised.

At the University of Virginia REC work has been continuing (1) to design and test new methods of skin and skeletal traction that will maintain adjustable distraction force on the spine during patient transport, in-bed positioning and through radiologic examination over several days of treatment.

Description - The traction bow was fabricated from polyester based fiberglass tubes that slip fit together with a 24" overlap. The lumen of the tubes served as the guide for the elastic tensioning cord accessible on the proximal end of the traction bow to a tensioning take-up reel at the distal end (Figure 1). A length adjustment from 68" to 80" was built with 4" increments. At each change in length the larger tube could be locked to the inside tube by a fiberglass thumbscrew. The smaller tube on the proximal end was built with a 45° bend and a 1.5" diameter pulley to guide the elastic cord from the head to the tension take-up reel driven by a reversible lever drive and ratchet.

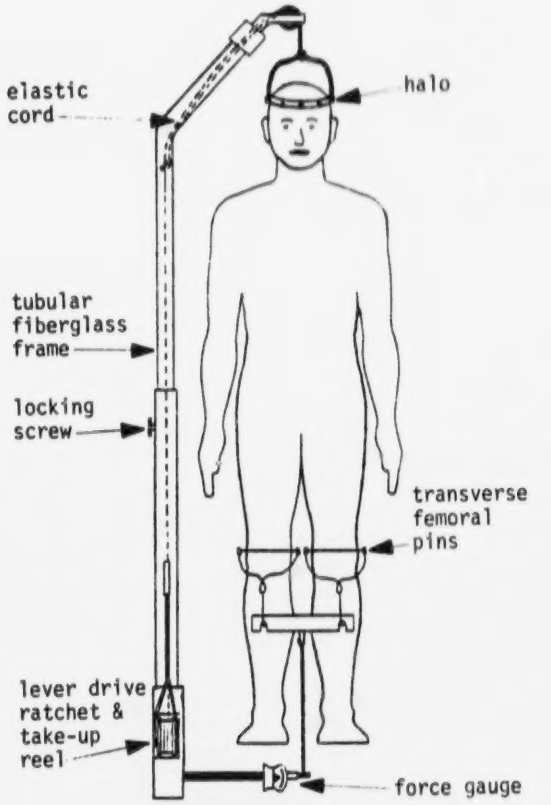

Figure 1. Schematic view of the traction bow applied for halo-femoral traction.

A nylon rope tied to the elastic cord is wound on the take-up reel to develop up to 80 lbs.

of tension in the elastic which was fastened to the halo or head halter and transmitted to the spine for traction. The traction load at the distal end of the spine was applied through transverse femoral pins for skeletal traction or through pelvic halter for skin traction. The halter or the femoral pins were attached to a 12" torque wrench welded to the base of the take-up reel. Monitoring the applied traction load was accomplished by the gauge on the torque wrench recalibrated in pounds of force.

Results - The elastic cord and traction bow design was used on a 25 year old man with T8 complete paraplegia (Figure 2). The patient was transferred from 40 and 50 lbs. of hanging weight traction onto the traction bow, in his bed. At 30 lbs. of elastic tension the distraction force was clinically judged to be equivalent to the previously higher load. The patient, in his bed on the usual spinal cord mattress, immediately reported increased comfort with the traction bow. He could be easily turned side to side and the bow relocated on either side of him for easy perenial care and cleansing. The patient was transported on a stretcher to radiologic examination under 30 lbs. of traction where the CAT scan showed effective distraction and stabilization at the fracture site without any interference from the traction bow through the gentry. The patient continued to remain in the traction bow for 5 days until surgical stabilization of his thoracic spine.

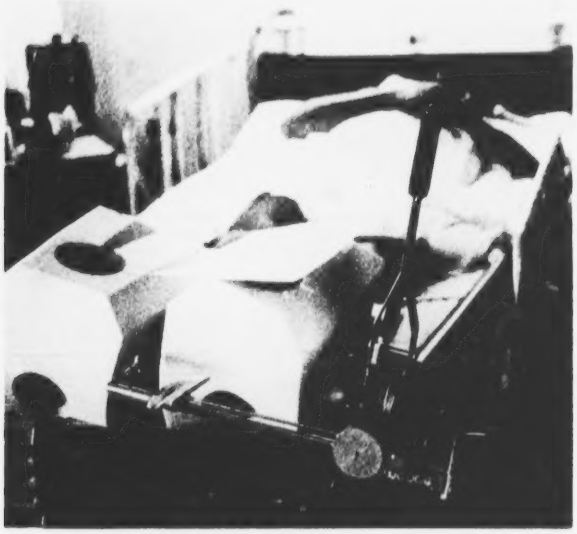

Figure 2. Distal end of the traction bow with ratchet drive and force gauge on left side of the patient.

Conclusion - The traction bow with adjustable elastic tension was well received by the patient and the staff on the spinal cord injury unit and in radiology. The patients comfort and care could be improved with less difficulty to the nursing staff. Furthermore, the patient could be kept on the usual body support system and transported under traction through CT scan or other myelogram while maintaining distraction and immobilization of the fractured spine.

Acknowledgement - This project was supported in part by NIHR Research Grant #G00-82-00026.

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PROTECTIVE HEADGEAR FOR DISABLED CHILDREN

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ABSTRACT - To manufacture custom-formed protective headgear, techniques developed for seating systems are being applied. The helmet's liner is custom-made using polyurethane foam or foam and beads, and inserted into a prefabricated shell. Cost savings are expected to be significant.

RÉSUMÉ - Des techniques mises au point pour réaliser différents sièges sont appliquées à la fabrication de casques protecteurs ajustés. La garniture des casques s'ajuste au crâne grâce à une enveloppe remplie de mousse ou d'un mélange mousse/particules de polyuréthane, permettant des économies d'argent importantes.

INTRODUCTION

At the Ontario Crippled Children's Centre, certain neuromuscular disorders are seen that cause young children to fall, have seizures or experience severe attacks of tremors that can result in injury. Rather than restrain these youngsters, every effort is made to facilitate for them the greatest degree of mobility consistent with their ability to manage safely. The solution is to provide one of two types of protective headgear: commercially available helmets designed for the disabled, or helmets adapted from those used in such sports as hockey. They are relatively low in cost ($25 - $75), however, their protection is limited to minor falls and bumps and cosmesis is generally poor, sometimes to the extent that parents refuse to let their children wear them.

There are two additional disadvantages in prescribing these helmets. Unless fitted with a chin cup, the helmet may be worn lopsided. If a chin cup is included, tightening the straps that hold the chin cup to the helmet applies pressure to the lower jaw of the child, resulting in possible orthodontic difficulties. The second and more serious drawback is the paucity of protection afforded the jaw and teeth in uncontrolled falls. In the Centre's experience, damage to the teeth is often severe, resulting in lengthy hospital stays and associated costs.

In response to these needs, the Department of Prosthetics and Orthotics at the Centre has developed a custom-molded helmet designed to provide a high degree of protection to the head, face, teeth and lower jaw. It is made of high density polyethylene vacuum-formed over a plaster cast of the patient's head. This cast has been markedly modified to provide space for a padded liner, and built up so that the chin cup and the helmet's front edge project far enough forward of the face to protect the teeth and nose. Since the chin cup is part of the helmet, it is held close to the chin, yet does not touch it, and thus provides good protection while overcoming the danger of restricting the lower jaw's growth. The drawback is the cost: $540 per helmet (labour, overhead and materials), usually a prohibitive amount for a parent to supply or to find funding for. Nonetheless, the need for this headgear is so great that seven have been dispensed to date.

In mid-1983, the Rehabilitation Engineering Department at the Centre started development work to reduce the cost of fitting the helmet, while maintaining a high degree of appropriate anatomical protection, good cosmesis, unobstructed vision, and custom fit of the liner and chin pad. This paper discusses the proposed approach to the problem, the work accomplished to date, and the areas still requiring development. In general, the present protective features of the custom-molded helmet are retained. However, instead of molding the outer shell to suit the shape of the head, a liner will be custom-made to fit intimately between the head and an outer shell, which has been previously selected from a range of consecutively sized, prefabricated shells to provide the closest fit to the child's head. There are two approaches being developed.

FOAMED POLYURETHANE LINER

The first relies on obtaining a model of the child's skull and then fashioning the liner to fit between the shell of the helmet and this model. The result is a custom liner between an irregularly shaped object (the head) and a standard, prefabricated shell. This approach is expected to facilitate the fitting of uncooperative children.

To reduce the time required in obtaining a replica of the skull, a specially designed measuring cap (see Fig. 1) was developed. It is similar to a large helmet, but incorporates adjustable pegs on its surface. The cap is placed on the child's head and the pegs moved in and locked into position once they touch the skull. The cap is then removed, and its interior filled with rigid polyurethane foam. After the foam has polymerized, the cap is removed, leaving a spherical piece of foam with holes where the pegs once were. The bottoms of these holes define the shape of the skull. The foam is then sanded until the holes just disappear - thus leaving a male model of the patient's skull. If the model needs to be built up, the material is simply not taken off, and instead the holes are used as depth gauges to indicate how much material has been left.

The foamed polyurethane liner is a full contact liner that provides stabilization on a child who suffers tremors, or who attempts to remove the helmet. The appropriately sized prefabricated helmet is selected, and the rigid foam model of the skull covered by a 3mm thickness of Plastazote™, which has been thermo-formed over the foam model. The liner is obtained by pouring flexible polyurethane foam between the helmet and the rigid foam model of the skull. The foam expands to fill all the spaces and then polymerizes, yielding a custom, padded liner. The plastazote acts as a barrier between the expanding foam and the skull's model during this procedure, and later serves as a durable, perspiration-proof barrier when the helmet is being worn. These techniques have been successfully used, and required two hours to produce a male model of the skull and the liner. Allowing an additional three hours to fit the chin cup and finish the helmet, the total cost (including $50 in materials) will be $260, a savings of $280 (52%) over the current model.

MOLDABLE POLYURETHANE LINER

The second proposed technique will be based on the Bead Seat Insert System developed at the University of Tennessee (Hobson et al, 1983). The liner will consist of two pads in the helmet, one at the front to provide suspension for the anterior edge of the helmet and keep it forward of the soft tissues of the face, and the other between the occipit and the posterior portion of the helmet to fully stabilize the helmet and provide padding in case of a fall backwards. Each pad will consist of a pouch into which is added a mixture of polystyrene beads and a two part microcellular (BASF Series 5000) polyurethane adhesive. The pouch is sealed and the materials kneaded together to form a viscous, moldable composite of beads and urethane. The orthotist has several minutes in which to shape the pad appropriately before the urethane polymerizes. The finished pad is a shaped composite of beads (to give lightness and some impact protection) and flexible polyurethane adhesive all contained within a pouch impervious to bodily fluids.

The essential advantage this technique has over foamed polyurethane is that the pads can be molded using the patient's own head, thus eliminating the procedure of taking a plaster wrap or using the measuring cap. Unfortunately, the method will only work with a cooperative child. Developmental work remains to pick materials for the pouch.

Currently, four molds for the prefabricated helmets and chin cups are being made to cover our target population. The skull and chin cups will be vacuum-formed out of high density polyethylene. The chin cups will be attached to the helmet by rigid plastic straps, and secured by snap-type or "common sense" fasteners. In case of deliberate attempts at removing the helmet, quarter-turn or "snapslide" fasteners will be used.

SIGNIFICANCE

The anticipated cost of a helmet produced using the measuring cap and a foamed polyurethane liner is $260. If the moldable liner is suitable, three hours labour and $50 in materials should be required, for a total cost of $170, or a 68% reduction in cost. The cost of repairing the damage these helmets are designed to prevent also is a factor. An abcessed tooth requiring a root canal and crown costs $580, and current hospital costs are $375 per day. In a typical scenario, a child who has fallen and hit his head may be admitted into an active treatment hospital for overnight observation or for treatment. A simple admission of only one day is sufficient to recover the cost of providing protective headgear.

Once the developmental work has been completed, the techniques would be widely disseminated. The molds would be made available, while all other materials are readily available on the market. A clinic not equipped with vacuum-forming equipment could purchase the shells and chin cups. Acquiring the measuring cap is not essential; the mold may still be obtained by plaster casting, although at increased costs.

The incidence of epilepsy is 1% of the population (Sands et al, 1977). Of these people, 20% find little or no relief from medication, and 10% (Gastaut et al, 1975) suffer grand mal seizures. In Canada, this means 5000 people could benefit from appropriate protective headgear. Cerebral palsy occurs in 1 in 700, and if 5% are considered to be ataxic, a further 1750 people may require protection. Clearly, a cost reduction of the size expected as a result of this work will have implications for the health care delivery system on a continuing basis.

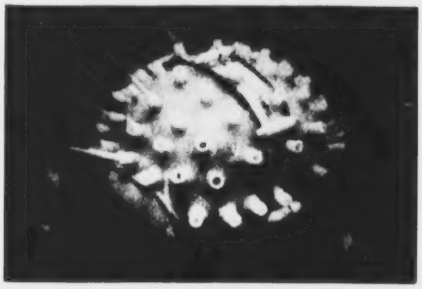

Figure 1: The prototype fitting cap.

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RE-EVALUATING THE VOLUNTARY CLOSING TERMINAL DEVICE: NEW DIMENSIONS IN PERFORMANCE, FUNCTION AND NEURO-MUSCULAR FITNESS

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ABSTRACT - Traditional mechanical terminal devices are passive prosthetic aids which limit amputees' bilateral capabilities. The GRIP voluntary closing device offers a natural prehensile configuration, greatly increases gripping capacity, and provides neuro-muscular stimulus for improved bilateral performance.

RÉSUMÉ - Les mains artificielles courantes sont des prothèses passives à possibilités limitées. La prothèse GRIP à fermeture volontaire présente une configuration préhensile naturelle, augmente considérablement la capacité de prise et fournit un stimulus neuro-musculaire qui améliore les performances bilatérales.

A terminal device is an appliance or instrument which replaces the natural hand and is attached to the distal end of a prosthetic arm. Terminal device has traditionally referred to a "split hook" but generally can refer to any type of an attachment.

Body power has been the reliable means of prosthetic terminal device control for over three decades. Voluntary opening (V.O.) and voluntary closing (V.C.) are the choices available, but V.O. has been the standard choice until recently. The systems are exactly opposite in operation. V.O. requires the amputee to pull "fingers" of the terminal device *open* with cable tension, then relax allowing the device to grasp an object. With V.C. the user applies and maintains cable tension to pull the "fingers" *closed* to grasp and hold. Thus, V.O. devices operate passively in that no muscular effort is required during holding, much like a passive vice. V.C. devices operate actively as they require constant muscle force to grasp and hold as does the anatomical hand. Traditional V.C. terminal devices, however, were equipped with semi-automatic locking mechanisms which eliminated the muscular effort required during holding. Because this passive operation is opposite to the way the natural hand works, I believe the benefits of true V.C. systems were never realized with traditional technology.

The potential merits of true voluntary closing control have been elaborated upon since the early 1950's. Klopsteg and Wilson in *Human Limbs and Their Substitutes* (1) made this qualified statement: "When weighing the considerations, it is apparent that the voluntary closing terminal devices present the most desirable features, provided only that engineering problems can be worked out satisfactorily."

The designs of the time, however, characterized by the APRL, Miracle, Pecorella, Becker, Trautman, and Sierra systems unfortunately did not adequately solve the engineering problems referred to in the quote. Today only two V.C. hook designs remain as vestiges of that era, and they are used very infrequently. V.C. hands, such as the Miracle and Pecorella were phased out and replaced by V.O. hand systems, which today are disappearing due to the advent of fully articulated electromechanical (bionic) hands.

"A Terminal Question" (2) reviewed and challenged the criteria used in the design of previous mechanical terminal devices and proposed alternatives. These have been incorporated into a new design in V.C. devices, the GRIP (3) Prehensile Action terminal device, introduced in 1980. The GRIP has combined a forefinger and thumb configuration with a non-locking V.C. control system requiring constant cable tension for holding and therefore constant neuromuscular effort. The GRIP has a narrow laminated steel construction and a size and weight closer to that of an adult natural hand.

A 1962 study by Dr. Mann (4) supports the opposed thumb design of the GRIP rather than the forceps shape of traditional hooks. Mann investigated the types of hand prehension used in various tasks and found that in "picking up objects" palmar, cylindrical, and lateral prehensions rated 40%, 21%, and 24% respectively while tip and hook prehensions were each used less than 10%. Analyzing "holding objects for use," he discovered that palmar prehension was required 81% of the time while all the other forms of grasping rated less than 10% of usage each. GRIP devices primarily duplicate palmar and cylindrical types of prehension but also have tip and hook capacities. Most split hook designs offer only tip, lateral, and hook capacities; therefore, they do not duplicate the majority of natural hand functions.

Gripping strength is a prime factor for evaluating terminal device performance. Amputees require bilateral capability for performance of most tasks. Split hooks and even myo-electric devices produce a maximum of 25 to 30 pounds of gripping force. The adult male and female can generate over 100 lbs. and 60-70 lbs. respectively with their hands. Taylor (5) found that an amputee could generate 61 lbs. of cable pressure with just a shoulder shrugging motion and in excess of 55 lbs. of force with either arm extension or flexion motions. Given this data, it is obvious that certain terminal devices limit the amputees' performance because they do not take full advantage of the amputee's muscle force potentials.

In contrast, an unpublished report evaluating GRIP devices conducted by Hauser Labs of Boulder, Colorado, (6) indicates that an amputee with 50 lbs. of cable tension could generate gripping prehension of approximately 100 lbs. in the innermost palmar grasping area of the device. This force is roughly equivalent to the adult male's palmar prehension capabilities and a prerequisite for true bilateral control, function, and capability.

Furthermore, to be competitive, an amputee is required to perform a full spectrum of activities. These include high performance tasks using gross motor control and reflex as well as tasks using fine motor control and dexterity. White (7) in a preliminary study presented at the 1983 American Occupational Therapy Association National Convention reported that GRIP devices performed well compared to the #5 Dorrance hook in tasks requiring fine dexterity and motor control. She plans to continue investigating motor learning to determine if any variance in training time for measured performance exists between the #5 hook and the GRIP terminal device. White's initial study confirms the performance by GRIP devices on the sensitive end of the spectrum of activities and complements the Hauser Lab's results relating to the potential performance at the heavy-duty end of the same spectrum. The GRIP seemingly offers amputees improved performance and function over traditional technology, but what are the neuromuscular considerations?

Amputees commonly experience atrophy as the stump shrinks and the bulk and strength in the upper arm diminishes on the affected side. Therefore, neuromuscular fitness and improvement of the neuromuscular system is important to amputees. A balanced neuromuscular system can improve performance and further prevent the potential spinal deformation which can result through long-term unilateral overstressing of the upper body's musculature. Traditional terminal devices with the passive vice function have forced amputees to relax arm and torso muscles during gripping and holding. This is opposite to the human system which is conditioned to contract specific muscles for gripping and holding. I believe the unnatural action contributes to atrophy over time.

Preliminary evidence in a recent study (8) indicates that amputees equipped with GRIP terminal devices are experiencing a reversal of neuromuscular atrophy on the affected side. In one case, an amputee actually experienced such an increase in hypertrophy (growth) of the stump musculature that a new, larger prosthetic socket was required. Hypertrophy and strength gains seem to be common within periods less than ninety days. Therapists involved have reported rapid high levels of proficiency and an ease of learning not common with traditional and myo-electric technology. Control seems to be enhanced because of the innate proprioceptive sensations generated during contraction of the affected arm and shoulder muscles and also due to the direct stimulation provided by pressure of the body harness during terminal device operation. Interpretation and assimilation of these sensations occurs rapidly and becomes a substitute for the normal finger tip and palmar sensations no longer available. Amputees can again "feel" what is being grasped. This "feeling" has been absent in and therefore plagued traditional "hook" systems as well as the newer myo-electric systems. Control is improved if sensation is available.

All of the studies above have been conducted with physically mature amputees because the GRIP devices available exist only in adult sizes. Newer, smaller models using non-metallic materials are under development. We might postulate as to whether the same characteristics of performance, function and neuromuscular benefits will be observed in children using smaller GRIP devices. Child amputees and congenitally limb-deficient children certainly have a need to develop muscle mass and strength in their affected limbs as they mature. Too many adults who have had amputations as children developed disproportionately due to a lack of proper muscular-skeletal stimulation on the affected side. A terminal device which requires active muscle use and offers more total function and performance to the child might help eliminate this gross disproportionate physical development. The potentials are exciting!

In conclusion, the preliminary evidence indicates that the GRIP system offers most amputees improved bilateral performance and functional capabilities over traditional systems as well as the opportunity for an improved neuromuscular system for good health.

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A SIMPLE BI-PLANAR RADIOGRAPHIC TECHNIQUE TO ASSESS FOOT DEFORMITIES

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This paper presents a radiographic technique to standardize foot position and provide comparable data for weight-bearing and non-weight-bearing patients, a tri-dimensional reconstruction technique allowing the assessment of foot deformities using spatial configurations of the conventionally utilized bi-dimensional parameters and new indices. The mean error for the tri-dimensional parameters obtained, using the proposed technique is approximately 5 mm.

Une méthode radiologique normalisant la position des pieds avec charge, ainsi qu'une technique de restitution tridimensionnelle et sa validation sont présentées. Elles permettent l'évaluation quantitative des déformations du pied à l'aide d'indices spaciaux associés aux paramètres bidimensionnels couramment utilisés. L'erreur moyenne est estimée à 5 mm pour les mesures de longueur.

The objective of a radiographic assessment of foot deformities is to obtain reliable information about their pathoanatomy. Dorsiplantar (DP) and lateral (LAT) radiographs are routinely used for this purpose. They are obtained with the patient assuming different positions: standing when possible, or in supine lying. Specific radiographic views are taken to quantify a given deformity. If additional radiographs are required, they are often viewed separately. The clinician usually quantifies a spatial foot deformity from its projection in a single plane, namely that of the radiograph. These techniques of obtaining DP and LAT radiographs may lead to inconsistent measurements.

To improve the reliability of radiographic data, the following elements need consideration: (1) foot position, (2) the weight-bearing or non-weight-bearing attitude of the foot and (3) the relative magnification of the radiographic image viewed.

This paper presents an apparatus to standardize foot position and simulate weight-bearing effects in the feet for both ambulant and non-ambulant patients, a reconstruction technique which transforms planar data into spatial data as well as its validation.

PROCEDURE TO OBTAIN STANDARDIZED RADIOGRAPHS

For taking standardized radiographs of the feet, the apparatus designed by Sibille et al.,(1981) shown in Fig. 1 is positioned at one end of the examining table. The subject lies supine on the table with his hips and knees flexed so that his feet can rest on the device's 15° inclined platform (1). The feet are restrained by means of straps applied to the upper third of the shanks and to the ankles. To simulate weight-bearing effects, a force equivalent to the patient's body weight is applied by means of a power screw (4) and compression spring (5) and transmitted through a cushioned block (6) to the patient's knees. Care is taken to ensure that the line of application of the force is parallel to the longitudinal axis of the shank. The slots (a) and (b) accomodate the x-ray casettes for the DP and LAT views respectively.

Two wires which define an orthogonal X-Y reference system and 8 spherical markers needed for the reconstruction technique are embedded in the platform (1). For the first of a pair of stereoradiographs, the source is located at a distance of 750 mm and positioned so that the x-ray beams are normal to the second metatarsal. For the second radiograph, it is moved laterally by 15°.

RECONSTRUCTION TECHNIQUE

The two steps taken to transform the planar data to tri-dimensional indices are recognizing a point on the object, on each image and determining the spatial position of the point.

The difficulty in recognizing distinct points on each bony image necessitates the use of special techniques, namely the midpoint of a contour and the area centroid. The midpoint of a contour is used when a smooth articular margin such as that of a metatarsal head can be delineated. The area centroid is used for bones, such as the talar neck, which have indistinct end points of their contoured margins. For details the reader is referred to Sirois et al. (1983).

The identified bony points and the reference markers are digitized on a digital table connected to an Apple IIe computer for data processing. A computer program transforms the bi-dimensional data into spatial coordinates by means of a Direct Linear Transformation Method (DLT) as described by Marzan and Karara (1976).

A schematic representation of the foot illustrated in Fig. 2 is obtained by connecting the points with various line segments after consideration of the bone shape and the normally occurring movements at its articulations. Long slender bones of the rays are represented by a line segment and the irregular shaped bones of the tarsus are represented by three line segments forming a triangle.

VALIDATION

To verify the reconstruction technique, three pairs of stereoradiographs of a skeletal foot were taken. Mean values were used to calculate six parameters which were compared with those obtained by direct measurements. These values and two others are presented in Table I.

The mean difference between the measured and calculated tri-dimensional values are approximately 5 mm. A comparison of the measured values with the corresponding bi-dimensional values gives a mean difference of approximately 7 mm. The difference between this value and that obtained using the proposed technique is 2 mm for length measurements of bones located in a plane parallel to that of the radiograph. One assumes that a greater variation will be encountered for angle measurements and lengths of bones spatially oriented. The mean variation between the bi-dimensional values and their corresponding projected tri-dimensional values in the X-Y plane is approximately 3 mm for length and 4° for the angle measured.

In addition to the conventional measurements the tri-dimensional values allow development of parameters not available with the conventional planar radiographs due to bony superimposition. For example, the angle of metatarsal torsion, which is the angle subtended by the lines joining the I and V metatarsal heads and bases respectively is 26°.

In summary, the technique described gives a means of standardizing the foot position and obtaining radiographic data which are comparable for weight-bearing and non-weight-bearing subjects. It reduces the errors due to magnification and allows for a more rigorous assessment of the spatial deformity. This technique is routinely used in the study of cavus foot in Friedreich's ataxia and equinovalgus of the foot in cerebral palsy.

ACKNOWLEDGEMENTS

L'Association Canadienne de l'Ataxie de Friedreich and the MacKay Centre for Deaf and Crippled Children have financially supported this project.

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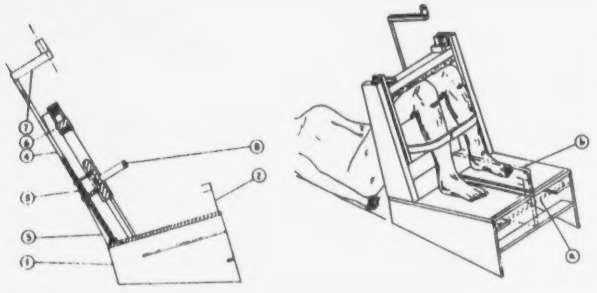

Fig. 1. Apparatus to standardize foot position and simulate weight-bearing

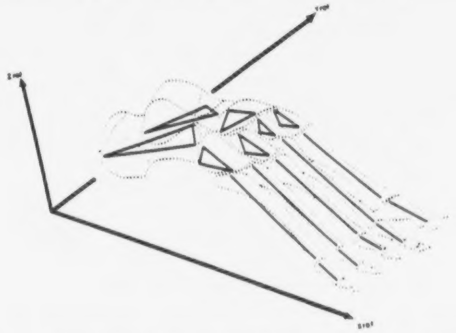

Fig. 2. Schematic representation of the foot

TABLE I. TRI-DIMENSIONAL AND BI-DIMENSIONAL PARAMETERS OF THE SKELETAL FOOT

Three-Dimensional Parameters	Measured 3-D Values	Calculated 3-D Values	Projected 3-D Values	Calculated 2-D Values	Two-Dimensional Parameters
Length (mm) of the longitudinal axis of:					Length (mm) in the DP view of:
metatarsal 1	56	64	49	54	metatarsal 1
metatarsal 2	66	65	58	54	metatarsal 2
metatarsal 3	73	62	53	56	metatarsal 3
metatarsal 4	59	55	50	56	metatarsal 4
metatarsal 5	60	55	52	56	metatarsal 5
Width (mm) of the forefoot	69	67	65	63	Width (mm) of the forefoot (DP view)
I - V metatarsal angle		33°	20°	25°	I - V metatarsal angle (DP view)
Angle of metatarsal torsion		26°			Corresponding angle not available

A NEW THREE-DIMENSIONAL MEASURING SYSTEM FOR THE NATURAL HAND AND FOOT

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ABSTRACT-----The object of this study is to establish a manufacturing method for a cosmetic cover, and a positive model which can easily process changes from a residual hand to a prosthetic device by using a three-dimensional measuring machine.

RESUME - La présente étude a pour but de mettre au point un procédé de fabrication d'un revêtement esthétique et d'établir un modèle positif qui peut facilement effectuer les modifications nécessaires pour adapter une prothèse à une main lésée au moyen d'un appareil de mesure tridimensionnel.

The demand for prostheses is at present small in Japan. Hence the technology has not made much progress in the last 15 years.

The object of our studies is to automatically measure the residual hand of a handicapped person and to systematically transfer the data obtained in this way. It is also our object to produce a microcomputer-based measuring system which can quickly process reductions, magnifications,changes, additions and corrections,and to produce a manufacturing system which can effectively utilize numerically controlled machines.

We have measured the hands of 25 normal persons and those of 6 handicapped persons in a manner which enables us to model a prosthetic device comparable to a normal hand. The outcome of these measurements has been to produce a prosthesis which is useful in the rehabilitation field. The prosthesis has been designed to have adaptive functions, such as various gripping modes,including that of 'shaking hands', for example.

Figure 1 shows the structure of the total manufacturing system. The system is divided into three parts. The personal microcomputer (PC-8801 NEC) is used as a host computer which collects data and executes a control command.

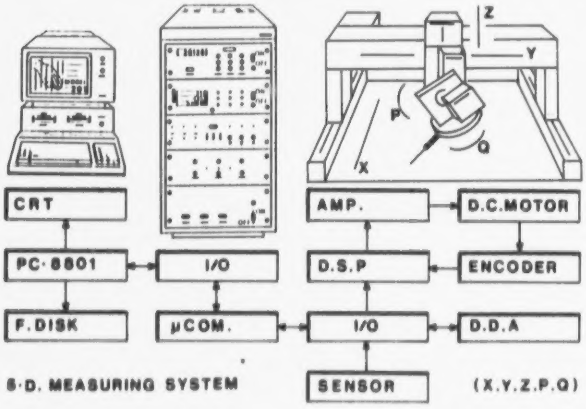

Figure 1 Total system

It manages the measurement the palm and the back of the hand, the formation of free corved surfaces of the living body, and also performs symmetrical transformations, magnifications, reductions, corrections,and shape amendments. It also issues automatic positioning instructions along the three axes to the measuring probe, using the BASIC language.

Eight DDA integrators, controlled by a Z-80 microprocessor,are used in parallel to calculate the interpolation of the shape.

The measurement and manufacturing processes utilize the same machine by interchanging the measuring sensor with a milling cutter. The sensor for measuring the living body is a capacitance type touch sensor (Length;50mm, Diameter;0.5mm, Response 10PF) which sends an ON/OFF signal to the host computer. The measurement error is ±0.02 mm.

Measurement and coordinate system

The coordinate system is composed of 5 axes, and is based on an orthogonal coordinate system with 3 degrees of freedom, and a rotational structure with 2 degrees of freedom.

We write (Xs, Ys, Zs) for a coordinate point in the orthogonal coordinate system of 3 axes, and (Xh, Yh,Zh) for the coordinates of a point at the tip of the probe . When we write P and Q for the angles of rotation of the probe along the 2 axes, the coordinates of the point being measured are

$$\begin{pmatrix} Xh \\ Yh \\ Zh \\ 1 \end{pmatrix} = \begin{pmatrix} CQ & -SQ & 0 & CQ\cdot L \\ CP\cdot SQ & CP\cdot CQ & -SP & CP\cdot SQ\cdot L+SP\cdot m \\ SP\cdot SQ & SP\cdot CQ & CP & SP\cdot SQ\cdot L-CP\cdot m \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} Xs \\ Ys \\ Zs \\ 1 \end{pmatrix} \quad \text{--------} (1)$$

$*CP = \cos P$ $*SP = \sin P$ $*CQ = \cos Q$ $*SQ = \sin Q$

Where, m is the axial distance between P and Q, and L is the length of the probe. Therefore, the data of the positive model generates an inverse transformation in the form of equation (1), and is transmitted to the slave computer.

Automatic measurement and interpolation

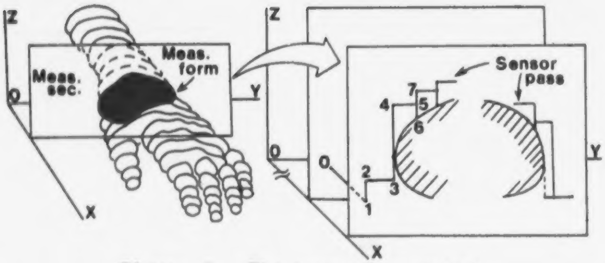

Figure 2 The measuring method

Figure 2 shows an example of hand shape mesurement. A subject extends his arms on a reclining chair, with elbows and forearms in a relaxed pose.
As the result of measurements from patients of 7 to 55 years of age, the arm was able to be kept in a position where it was not necessary to correct the measurement data for movements of the body.

As shown in Figure 2, we automatically measured about 1000 points in each section interval(3-8 mm) at a speed of o.8 s/point.

Figure 3 (a) is an example of the measurement of a finger amputee. Figure (b) is a diagram in which the wrist was corrected in accordance with a socket form in order to manufacture a cosmetic cover for a 7 year-old-girl.

Figure 3 (a) and (b) are examples of measuring automatically along 3 axes. Figure (c) is an example of measuring a foot by the control of 5 axes.

We have used B-spline and ellipse interpolation in order to obtain a smooth curve between sections. It is very difficult to interpolate a complicated object like a hand contains 5 fingers, but it is possible with the use of a new algorithm developed in this study utilizing B-spline. An ellipse interpolation is used to get a suitable roundness in the finger tips. This method of interpolation is very simple and suitable for a hand.

The cutter program of the positive model divides a measured model into two pieces (the upper and lower halves), and then is written in BASIC language and checed for possible tool correction and interference.

The milling of the model according to the measured data can be done automatically, using the same system.

We have obtained good results in the application of this system in the development of cosmetic prostheses.

Conclusion

The new hand shape manufacturing system has produced several merits by measuring the soft living body three-dimensionally and obtaining an identically shaped hand from the residual hand.

(1) Until now, it was impossible to store all the numerical data, but it has become possible to store the hand shape numerically on a magnetic disk.
(2) Previously, hand prostheses were designed from a simple, standardized length measurement, but standardization according to section shape and size has yielded useful results for the planning of an electrical prosthesis.
(3) The manufacture of an individually matched has become possible because a residual hand is reversed by microcomputer.
(4) In data operation, work which previously required a great deal of time, such as magnifications, reductions, additions, and eliminations, has become much easier.
(5) In addition to the utilization of the system in rehabilitation, it is possible to use various transformations to obtain an estimation of the shape of the hand in different positions (for example, a newtest hand for a patient with rhe matism).

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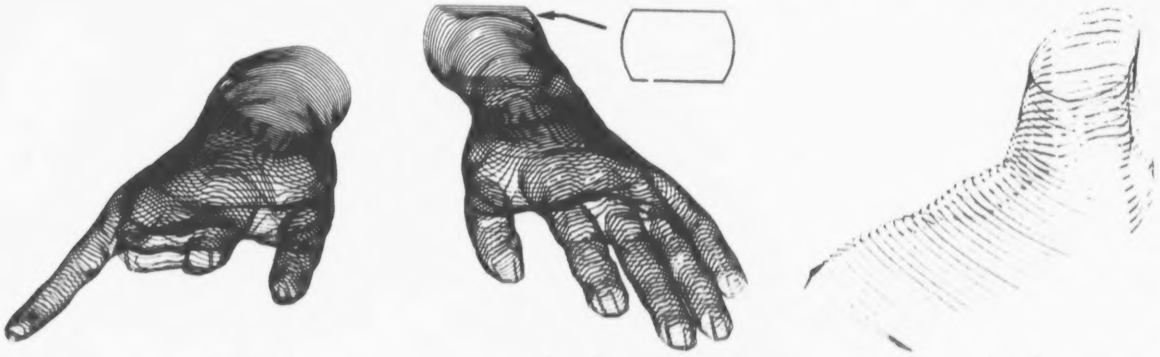

(a) (b) (c)

Figure 3 Measured and managed form

TRAITEMENT INTERACTIF DE FORMES ANATOMIQUES TRIDIMENSIONNELLES: APPLICATION À LA PROTHÈSE ORTHOPÉDIQUE

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RÉSUMÉ - Le développement des ressources numériques et de la conception assistée par ordinateur permet d'offrir un support puissant à la définition et la fabrication de prothèses. Cette présentation décrit le prototype d'un système développé dans le contexte de la chaussure orthopédique. Elle aborde les questions touchant l'acquisition, la modélisation et la modification interactive d'une telle forme anatomique.

ABSTRACT - Computer aided design and other digital ressources may offer a significant support for the definition and fabrication of prosthesis. This presentation describes a prototype work station developed for orthopedic applications. Various aspects involved in the 3-D acquisition of the shape of a foot, its modelling and interactive modification are considered.

La fabrication et l'ajustement de prothèses biomécaniques peut largement bénéficier de la technologie numérique contemporaine. En effet, diverses phases d'un tel traitement comportent des aspects quantitatifs auxquels la vision industrielle, la conception assistée par ordinateur (CAO), et la robotique peuvent directement contribuer. Une approche numérique offre une flexibilité exceptionnelle de traitement et de stockage de l'information et ceci à un cout rapidement décroissant qui en promet déjà une grande accessibilité. Ce point de vue est à l'origine d'une recherche menée en collaboration avec le Centre Hospitalier de l'Université Laval et le Centre Francois Charon (Québec) et qui a conduit à un premier prototype de support informatisé à la prothèse orthopédique.

Parmi les phases éventuellement les plus adaptées à une telle assistance technique, on peut signaler:

a - La mesure de la forme de l'organe à laquelle la prothèse doit s'adapter; la distribution des points d'articulation et de charge.

b - Une définition des corrections qui puisse efficacement s'appuyer sur de telles données et sur une modélisation biomécanique, dans un cadre d'utilisation adapté aux besoins de la profession médicale.

c- Des moyens permettant un suivi quantitatif d'un traitement.

d- Une démarche de classification permettant de comparer et d'ordonner les mesures obtenues sur une population, notamment en vue de normalisations qui pourraient réduire les couts de fabrication.

e- Le recours aux techniques de commande numérique pour l'assistance à la fabrication.

Les travaux en cours ont partiellement répondu aux éléments a, b et c. Quoiqu'orientés vers la prothèse orthopédique, les éléments techniques qui ont été développés sont généraux pourraient etre adaptés à d'autres applications cliniques ou la mesure et la manipulation d'une forme sont impliquées.

L'acquisition de la forme est réalisée au moyen d'une caméra de conception originale qui exploite le principe de la triangulation active. La surface du pied d'un patient, supporté par une plate-forme horizontale, est successivement explorée par un faisceau lumineux dont l'orientation précise est connue. Simultanément, une caméra numérique détecte la réflexion de ce faisceau et en fournit les coordonnées spatiales angulaires. Cette opération est répétée selon un système de coordonnées cylindriques qui segmente la forme en 32 coupes horizontales, elles-memes définies en 32 positions périphériques, alors que le couple source lumineuse - caméra effectue une rotation autour du pied. L'ensemble est géré par un microprocesseur qui effectue les calculs nécessaires et qui stocke ces résultats bruts sur support magnétique. Le temps requis pour cette acquisition primaire est de l'ordre de la minute et la précision, après lissage des données, de l'ordre du millimètre.

La représentation interne est basée sur celle dite 'du cylindre généralisé'. La forme est alors décrite par des sections disposées le long d'un axe longitudinal et modélisées par un développement de Fourier de la distance radiale en fonction de la position angulaire. Des essais ont montré qu'une suite tronquée au 10 premiers coefficients fournissait une précision satisfaisante, notamment lorsque la distance radiale est au préalable soumise à une transformation non linéaire qui tend à 'cylindriser' la forme. De plus, étant donnée la continuité spatiale de la forme, l'évolution de ces coefficients est une fonction douce de la hauteur, et peut donc etre décrite par un polynome d'ordre peu élevé (e.g. 3 ou 4). On aboutit ainsi à une représentation fort compacte - 300 à 400 octets - pour l'ensemble de la forme.

Quel environnement fournir au personnel clinique afin de supporter efficacement la manipulation et l'édition de telles formes? En plus de fournir une visualisation graphique adéquate et une mesure quantitative de diverses caractéristiques de base, il importe de définir un langage de modification qui soit clair, pertinent, et décomposable en opérations élémentaires dont les résultats puissent etre facilement envisagés avant leur application. De plus il est apparu utile que cette édition puisse s'effectuer selon deux modes distincts. Un premier, dit 'intéractif' permet d'exploiter les ressources du graphisme numérique intéractif où l'usager peut agir directement sur la forme. Un second, de type 'paramétrique', où la forme est automatiqument soumise à une suite de transformations décrites par des paramètres numériques,ce qui facilite la production de familles de formes.

Huit primitives de bases constituent le noyau d'exploitation de l'environnement intéractif. Certaines sont globales, et s'appliquent à l'ensemble de la forme; d'autres, locales, ne s'appliquent que sur une région partielle de la forme du pied.

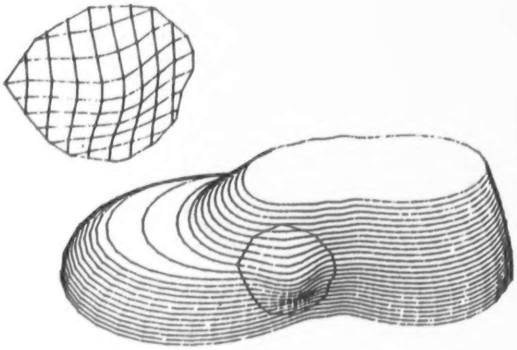
Les trois premières permettent de simples modifications d'ECHELLES, soit globales, soit selon des axes privilégiés, soit encore circonscrites à une région.

Ls primitive de COQUILLE, globale ou limitée à une dimension, engendre une nouvelle forme qui s'inscrit à une distance déterminée de, et selon la normale à, la forme originale.

La primitive de FLEXION associe la forme à un objet plastique. Le plan de flexion est d'abord choisi en orientant la forme dans l'espace. La forme désirée du plan après flexion est spécifiée par des points de consignes fournis au moyen d'une tablette numérique, points ensuite lissés en fonction de flexion continue. Une vérification topologique est effectuée afin de s'assurer qu'aucun point à la surface de la forme initialle ne se retrouve à l'intérieur de la nouvelle. Si cela est le cas, un traitement d'interpolation locale est effectué afin d'assurer la continuité physique de la forme.

Dans la primitive de TORSION, la forme est assimilée à un empilement de sections centrées sur un axe spécifique. Cet axe ayant été choisi, une fonction précisant l'angle relatif de rotation de chacune de ces sections est fournie intéractivement et la forme alors remodelée.

Finalement, ces primitives sont complémentées par celle de la PIECE LOCALE, qui synthétise l'addition (ou la soustraction) d'un volume à la forme de départ. Elle est analogue au couteau d'un sculpteur. La Figure illustre son action. La forme est d'abord orientée afin de présenter la face pertinente. Puis le pourtour de la région où la modification doit s'effectuer est précisé, de meme que la position du sommet de la pièce, son amplitude, et un coefficient de raideur de sa pente. La forme de cette pièce est alors calculée en tenant compte de ses conditions frontières, afin d'assurer sa compatibilité avec la forme principale. La Figure montre un exemple de forme totale après 'collage' de la pièce. Cette primitive a été concue afin de permettre des modifications locales à la fois souples et précises, comme elles seraient nécessaires pour exercer une pression ou au contraire définir un vide dans une région particulière de la prothèse.



Ces primitives sont gérées de manière à pouvoir etre facilement enchainées, chaque édition de la forme, une fois validée, pouvant servir de fichier de départ pour la modification suivante. A ceci s'ajoute le support à l'extraction de caractéristiques géométriques de base, tels surface ou volume d'une région, distance entre points particuliers, ou vue d'une coupe à travers un plan arbitraire.

Ce projet vise la réalisation d'un poste de travail éventuellement autonome et peu couteux. Le prototype de laboratoire a été réalisé sur microprocesseur 8 bits, sur lequel l'utilisation d'une unité arithmétique et d'un disque virtuel a permis une performance suffisante pour explorer les aspects ergonométriques (10 - 30 sec/primitive). Ces ressources seront maintenant transportées à un processeur plus puissant, et nous espérons pouvoir entreprendre une évaluation clinique sous peu.

Ce projet a été supporté, en partie, par la Fondation Yvon Deschamp, le Conseil de Recherche en Santé du Québec, le Centre Francois Charon, et l'octroi A5274 du Conseil de Recherche en Science Naturelle et Génie du Canada.

SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 8

INDEPENDENT LIVING II - ROBOTICS/
VIE AUTONOME II - ROBOTIQUES

VOCATIONAL APPLICATIONS OF A ROBOTIC AID

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ABSTRACT - The Veterans Administration/Stanford University Robotic Aid was developed to give individuals with high level disabilities increased control through the ability to manipulate objects in their environment. The vocational tasks discussed in this paper were designed using the Interactive Evaluation Model developed by Engelhardt et al. (1) to investigate the vocational potential of a robotic aid and to fill a need identified by several users.

RÉSUMÉ - Les Vétérans Administration/Stanford University Robotic Aid a été créé pour fournir aux personnes atteintes d'un haut degré d'invalidité la possibilité d'exercer une plus grande maîtrise de leur environnement en leur permettant de manipuler des objets. Les tâches professionnelles discutées dans cette communication ont été conçues à l'aide du Modèle d'évaluation interactif mis au point par Engelhardt et al. (1) pour étudier le potentiel professionnel d'un robot et pour combler un besoin signalé par plusieurs usagers.

INTRODUCTION

Until the 1950's rehabilitation efforts were focused primarily on the replacement of lost limbs. In the mid 50's emphasis was placed on vocational rehabilitation when Mary Switzer, then head of the Office of Vocational Rehabilitation, persuaded Congress to expand support for rehabilitation. (2) It has been only recently that:

> "...changes in the vocational rehabilitation programs have mandated a commitment to dealing with the 'more severely disabled' people, and outcomes to be sought now include not only the ability to function within the work force but also to live more independently." ...These changes necessitate a significantly different approach to vocational rehabilitation because "...the principle of independent living does not necessarily imply that one is free of the need for services, but rather that those services are under the control of the disabled person." (3)

Independence is an important psychosocial, as well as health care economics issue. The level of independent actions a disabled person is able to achieve impacts on the resources that must be invested in the care of that individual. "Severely impaired individuals have little direct control over their personal space. They are unable to use the vast array of gadgets that most of us depend on. Independent living for these people requires assistance from other people and devices." (4) The VA/SU Robotic Aid has been developed on the hypothesis that robotics technology applied to rehabilitation can assist a severely disabled individual in regaining control of his/her environment and, therefore, increased independence.

BACKGROUND

The VA/SU Robotic Aid integrates state-of-the-art speech recognition and speech synthesis technology with existing robotics technology. The primary goal of the project is to give users "increased control and independence over their environments and to restore as many manipulative functions as possible". (5) The arm is a Unimation Puma 250 industrial robotic arm and controller, driven by a Z-80 based microcomputer. It has the capacity for input by voice, keyboard, head motion and joystick. Currently the arm can be controlled by voice, keyboard or a combination of the two.

Clinical evaluation of the system is an ongoing process at the RR&D center. User-specific training has focused on ADL (activities of daily living) and recreational tasks to date. Such tasks include food preparation, telephone and appliance use, painting, and manipulation of gameboard pieces. Many of these tasks were presented as challenges to the Rehabilitation Research Evaluation and Learning group (RREAL) by users and visitors to the RR&D center. (Many users have designed their own sequences too.)The vocational task discussed in this paper is no exception— several potential system users, in the last year, identified a need to have the robot open a file drawer, remove a file and then present it.

According to a 1981 report compiled by the Sensory Aids Foundation, return on investment (the ratio of income per year to investment required for the placement in a job) is significant even when expensive sensory aids are utilized. (6) Upon examination of the economic statistics of placing the disabled in the labor market, it becomes clear that research into vocational applications will be an important evaluation issue in determining future markets for this device.

METHODS

Assistive device development is often performed without any input from the intended user. Product development based solely on the designer's perception of user needs and wants often results in inappropriate and useless technology. (This problem of user/designer isolation extends across disciplines. Engineers are as much at fault as are health care professionals, administrators, and policy makers.) The Office of Technology Assessment refers to "appropriate technology" as technology that is developed or adapted in response to the needs, desires, and capabilities of disabled people..." (7): the Interactive Evaluation Model used in the development of this task, seeks to avoid the development of inappropriate technology by including the user in the design process.

Dean Cormany, a potential user of the robotic aid, was among those who had proposed the 'filedrawer' task to the RR&D evaluation team. Particular members of the team were chosen to work with Dean in investigating the feasibility of using the robotic aid to perform such a task. Members of this subgroup were from a variety of academic and experiential backgrounds: Dean is a system user, ABLEDATA broker, neuromuscular quadriplegic; Brodie Lockard, an evaluation team member, trained system user, graduate student in interactive computer education, C-1,2 respirator-dependent quadriplegic; and Karen Holloway, an evaluation team member, rehabilitation engineer, product designer.

Dean was instructed in the use of the robotic aid and spent several hours becoming familiar with its capabilities so that he could evaluate the robot's performance (of the filedrawer sequence) on the basis of his own experience. This instruction took place over the course of several weeks. During Dean's training period, Karen and Brodie worked to meet the challenge that Dean, and other users, had presented. (See figure 1.) Weekly progress reports were made to the evaluation team to gain additional insight into any problems or constraints that were affecting the task design. (It was at this point that another assistive device was fabricated: a shift-key lock that enabled Brodie to use the keyboard, in conjunction with voice control, to program the robot without the help of his attendant.) After this training period, the filedrawer sequence was demonstrated to Dean. His feedback, in conjunction with that of the RREAL group, led to the next iteration of the task design, which was then evaluated, and the cycle began again.

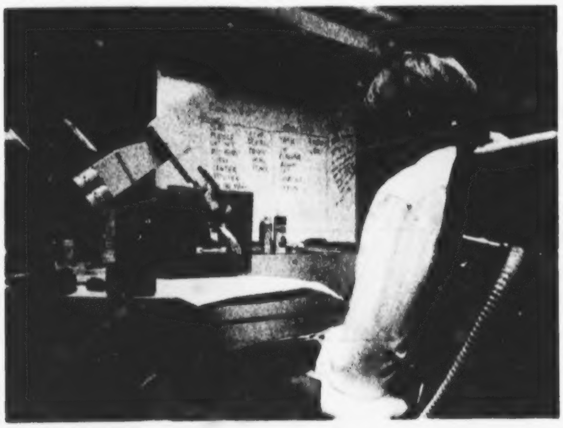

FIGURE 1. Brodie Lockard working on task.

DISCUSSION/CONCLUSION

Dean's input was vital to the development of an appropriate filedrawer sequence. The framework established by the evaluation model was the basis for this interaction, and for the approach taken for the task development. The model allowed Dean, as a user, to become a participant in the research that focused on issues specific to his needs. (8) (See figure 2.) Dean's initial suggestion enabled the RREAL group to target an appropriate need; continued involvement led to the development of an appropriate application of the robotic aid.

Further research demands refinement of the filedrawer task and new task development. In the process of evaluating this task, several other vocational needs were expressed (e.g. folding letters and stuffing envelopes, manipulation of appliances particular to an office setting). Thus far, the filedrawer sequence has only been tested in a research setting, the evaluation lab. If we are to remain within the framework used in the preliminary development of this task, then the task must undergo evaluation in a workplace. This field experimentation is necessary to determine the vocational potential of a robotic aid in real life settings. According to the Interactive Evaluation Model, rehabilitation counselors play a significant role in assessing task validity. Their input is needed to identify appropriate users and setting in which to test the vocational task. Again, user interaction will be important to the development of user- appropriate technology.

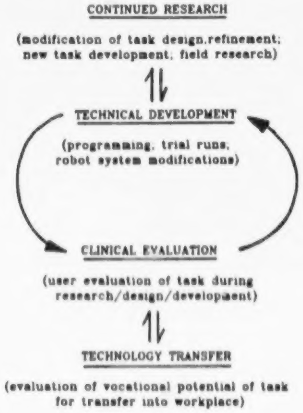
CONTINUED RESEARCH
(modification of task design,refinement; new task development; field research)
TECHNICAL DEVELOPMENT
(programming, trial runs, robot system modifications)
CLINICAL EVALUATION
(user evaluation of task during research/design/development)
TECHNOLOGY TRANSFER
(evaluation of vocational potential of task for transfer into workplace)

FIGURE 2

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A LOW-COST ROBOTIC MANIPULATOR FEEDING DEVICE

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ABSTRACT - A system has been designed at the Rehabilitation Engineering Center which uses a robotic manipulator as an integrated multipurpose device for handicapped individuals. One function of this system addresses the issue of feeding an individual with physical disabilities.

RÉSUMÉ - Le Rehabilitation Engineering Center a conçu un système de robot manipulateur faisant office de dispositif intégré universel pour les personnes handicapées. Une des réalisations de ce système est de permettre à des personnes ayant des déficiences physiques de se nourrir seules.

INTRODUCTION

The use of a robotic manipulator as an aid to the handicapped is an attractive concept, especially when one considers the many facets of care necessary to a disabled individual. Persons with limited physical abilities due to cerebral palsy, spinal cord injury, or any other disabling condition often have many functional needs beyond the scope of traditional therapy and rehabilitation. The use of a low-cost robotic manipulator to feed a disabled person is not only an economically sound method of filling this time-consuming need, it can also help free the individual from total dependence on other people.

DESIGN CONSTRAINTS

The major hardware for the system, including an Apple Computer and a Rhino XR-2 manipulator, was previously purchased. Extra hardware must be kept to a minimum to provide easy setup and change over to another assistance application. The system must be easy to use by the handicapped user, especially command input.

MONETARY CONSTRAINTS

For the Rhino/Apple system to be considered a realistic alternative to other commercially available feeding devices, it needed to be comparable in cost to presently used and third-party reimbursable methods.

Handicapped individuals in independent living situations most often receive their meals via a Personal Care Attendant (PCA). The estimated time required for a handicapped individual to be fed by another person is 3.5 hours a day, based on a 3 meal/day schedule, with 1 hour for breakfast, 1 hour for lunch, and 1.5 hours for dinner. Assuming that an attendant is paid approximately $4.75/hour, the calculated cost to an individual for the feeding of meals alone is approximately $6,068 annually.

A second alternative to the individual is the use of a commercially available "dedicated" device. These devices perform a singular function, and range in price (from $350 to $1,150) and in modes of access.

The proposed system, a Rhino Robot, Apple II computer, and several utensiles have a combined cost of approximately $5,000. Therefore, the system's cost falls within the range currently being funded by third-party payers.

HARDWARE SELECTION

The system has been designed so that there exists the possibility of using standard tableware with few additional devices. The basic set-up is as follows: a plate with a high rim sits on a turntable setting directly in front of the user, and a spoon with a modified handle sets above this and to the right, handle-up in a simple holder. The system is shown in figure 1.

FIGURE 1.

The turntable is inexpensive ($3) and is easily available from Rubbermaid. It is used to turn the plate during feeding to allow scooping from different areas. The plate is turned by drawing the spoon against the inside edge of the plate after scooping the food.

The plate currently used has one-inch edges that are ridged on the inside. It is made of glass so that the food items may be placed on it and heated in a microwave oven.

A spoon was chosen as the feeding implement to allow the greatest variety of foods to be picked up, and to provide safety to the user. The spoon is used with a specially modified handle. This handle was designed to allow a firm grasp by the robot hand, and to help insure correct positioning of the spoon in the hand. The spoon holder was designed to allow for quick, easy, and accurate acquisition of the spoon by the robotic arm.

SOFTWARE DESCRIPTION

Special software was developed to use in the training of the robot to perform the necessary tasks. A program was then written to accept user input to control these task motions. Special considerations were taken to insure smooth arm motion and easy command input.

The "BUILDER" program emulates the Rhino Demo program. Its capabilities include interactive single motor movement by keyboard control; monitoring of absolute number of steps from the "hard" home position; display of relative moves for each move sequence; and playback of recorded sequences of moves in both positive and negative directions. The values for the motor movements can be displayed and edited using the "EDIT" program.

Once the task movements have been developed, the files can be concatenated into one large file using the "COMBO" program. This file can then be used as input to the "EATER" program, which will then accept user input to execute any of the pre-programmed robot moves.

USER INTERFACE

The system is controlled by single letter task oriented commands. The commands used are tiven in table 1.

COMMAND	NOTES
I - Initialize	Indicate spoon position for initial setup.
G - Get Spoon	Will be ignored if spoon is in hand.
R - Replace Spoon	Will be ignored if spoon not in hand.
S - Scoop Food	Will get spoon first if not in hand.
F - Feed	Bring hand to mouth.
Q - Quit	If spoon in hand will replace first; then return to hard home.

NOTE: A move from hard home to soft home will preceed the first command given.

TABLE 1.

Each command will cause the system to perform a series of movements to complete a task, starting and ending at the home position. The software has been set up to perform certain tasks automatically. Also, if a command is unnecessary, it will be ignored. Examples of this are described in the "NOTES" of Table 1.

Commands can be input by typing them on the computer keyboard. A menu is provided for reference before each prompt for a command. A non-speaking person could use the system with a single switch scanning device, using a head switch or some other kind of simple switch to choose the command desired as the computer scanned the various commands.

The system is ideally suited to using voice input. This is especially suitable for a spinal cord injured person who has unimpaired vocal capabilities. One spoken word or phrase describes each of the command inputs. The voice control system must be trained by the individual user, and the voice patterns stored on a disk.

FUTURE CONSIDERATION

Several future improvements to the robotic feeding system have been planned. To speed up the arm movements and eliminate any "jerkiness," the controlling routines can be written in an assembly language or a compiled language such as "C." The system can be set up to use many different styles of tableware by using a separate plate guard that completely surrounds the plate and that has a textured inside edge. A detachable spoon handle could be made to hold many different styles of spoons.

The feeding routines could be taken a step further by programming the robot to pick up the plate, place it inside a microwave oven, operate the oven, then replace the plate back to the feeding position. Simpler expansions of the routine include using a napkin, serving liquids from a glass, and using a fork, although this involves many additional safety considerations.

CONCLUSION

The proposed approach to the feeding issue utilizes a robotic manipulator as a feeding device. It is not a readily portable system, nor is it currently aesthetically pleasing. However, unlike the commercially available dedicated devices, the robot has the potential for multiple functions. In addition to feeding, a function which alone warrants the system's cost, it is conceivable that the robotic manipulator could be programmed to assist with other daily living tasks and vocational activities. The system is not limited by a schedule, and has a multitude of possible access modes, from single switch input to voice control of routines.

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A LOW COST GENERAL PURPOSE PROGRAMMABLE MANIPULATIVE APPLIANCE FOR SEVERELY DISABLED

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ABSTRACT - The development of a low cost reliable medical robot easily programmed with a home computer is described. It is a bedside or work center installation. Acceptability for work in industry was considered paramount to maximize production.

RÉSUMÉ - La mise au point d'un robot médical fiable, économique et facilement programmable à l'aide d'un ordinateur individuel est décrite. Ce robot est prévu pour installation au chevet ou au poste de travail d'une personne. Son utilité pour les travaux dans l'industrie a été considérée primordiale pour en maximiser la production.

In 1982 we decided to apply our robotic expertise to development of a robotic appliance for use in the field of rehabilitation. A typical wish list was prepared, and updated after many consultations with severely disabled people and professionals in the long term care and rehabilitation. A wheelchair mounted version was forsaken for the first model to be developed as the wish list pinpointed a number of wheelchair-mounted-only tasks that require great precision (putting a key in a keyhole) and an orderly environment. Many of these tasks also require a high degree of master imput control that in itself is a major development project. We give primary emphasis to the work center approach as pioneered by Seamone at John Hopkins University[1].

The specifications for the first model are:

1. Mass produced sales price of arm and stand-alone control electronics under $5,000.
2. Both master/slave and programmed operating modes.
3. Programming to be done on any home computer. An Apple II was selected for the first prototype, and a Sinclair is being prepared for the second.
4. Complexity of service and maintenance to be kept simple enough to allow for local consumer audio or computer agency servicing.
5. Operation to be extremely "user friendly", with no operator training being required. Specifically, no knowledge of computer programming will be necessary, and no computer keyboard will be used.
6. The co-ordinate envelope is approximately human-sized.
7. The appliance must be portable, with total weight to be less than 20 kg.
8. Lifting capacity at worst geometry of 1.4 kg, and at most geometries of 2.3 kg.
9. Use in industry in light manufacturing to be underscored.

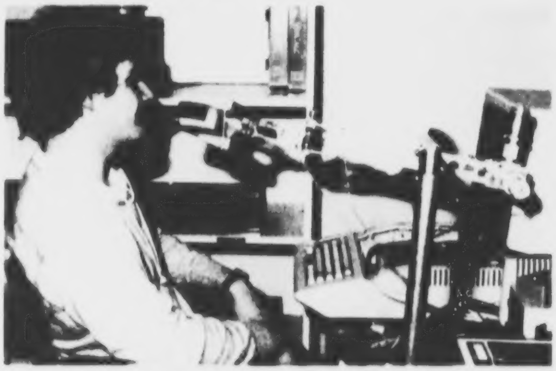

Figure 1. Shaving.

A mechanical drive system through gears and timing belts is used. The home computer, or "supervisor", addresses the arm via an RS 232 serial port. A "hand lead through teach" programming mode is absolutely essential. A programming pendant has an "on" switch, a hand "open/close" switch, and an "accuracy needed" switch. The robot hand is taken by the programmer or teacher from its parked position and is lead through the task, and then returned to park. After the program is in memory, it can be partially modified (such as velocity modification for part of the task). Voice imput is being used.

The "accuracy needed" feature was added as the controller software is constantly sampling positions and is often moving ahead before point position errors are nulified. When accuracy of one millimeter is required then the controller CPU is required to reduce the error in each point in the trajectory to zero before going on to the next point. This places a velocity restraint on the hand in this mode which is considered desirable.

Potentiometer feedback is used in the three degrees of freedom for orientation in the wrist. These give 256 steps in 180° for pitch and yaw, and 360° for roll. With the short lever arm to the center of the robot hand, that gives a nominal one millimeter accuracy. Commercial optical encoders with 1000:1 resolution are used for feedback in the upper three degrees of freedom for positioning. This maintains the same accuracy at the center of the hand. Velocity control is established as the derivative of the feedback values.

The on-board controller is based on a low cost 8 bit Motorola 6809 microprocessor which has a 16 bit internal arithmetic capability. It is programmed for proportional integral derivative computations for accurate well controlled positioning. The controller simultaneously handles seven channels for the six degrees of freedom plus the gripper, sampling point to point positioning at 400 cps. The teacher has a sampling control to distinguish between very accurate steps and general trajectories.

Two interchangeable hands are under development, one for handling small items (mouthstick, paper, etc.) and one for large items (telephone headset, carton of milk, etc.). Each gripper carries its own motor and gear train and potentiometer (model airplane control motors). A gripper rack is mounted with the appliance and the arm will change to the proper hand (if necessary) as part of the program being executed.

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BALANCED TRANSFER SYSTEM FOR THE SEVERELY DISABLED

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ABSTRACT - Balanced transfer system, commercially called Non-Gravity Lifter, was developed to release the physical duty for helper transferring bedridden disabilities between beds and baths. Having been in operation for three years at Hachiohji Independent Home in the suburbs of Tokyo, further development is demanded for sole control by the disabled user.

INTRODUCTION

Balanced suspension system in assembling factory holds heavy piece of parts to move to any directions with manual handling. The same mechanism is applied for transfer system of the disabled, who is held in a state to be lightly pushed or pulled in the room space, not to say in non-gravity state. The system operation is performed by the helper, not by the disabled user.

SYSTEM MECHANISM

The mechanism of system is taken as a balance of parallel links replacing the counterweight with air pressure.

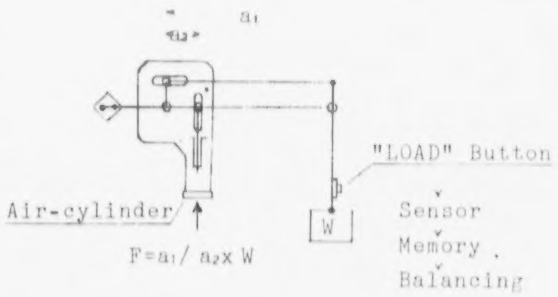

Figure 1 System Mechanism

Force F upward in air-cylinder gives the arm lifting force to maintain balance with load W. As well as up/down movement, 360 degrees rotation is free with swivel connector to feed air. Operational range of arm tip has the limitation shown as Figure 2. For the wider range of operation, the system is set on the ceiling-rail sliding along.

Driving power source is not electrical but pneumatic in order to keep it waterproof. Sensing and memorizing load pressure are also a-complished by pneumatic circuit.

FUNCTION

The disabled is to be transferred with the touch of helper's hands, always keeping humane relationship between both sides. Small operational force makes child or aged a useful helper. Another feature is the shortest transfer line realized by three dimensional movement of the arm within the operational range.

NEED IN FUTURE

A male user, who has enough strength in upper limbs, wants to apply the system for self-operating aid to transfer himself by kicking floor, pushing wall or pulling rail/rope set along his daily activities.

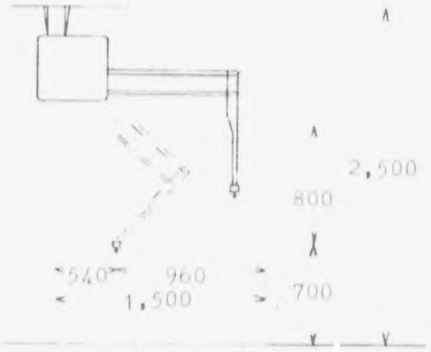

Figure 2 Operational Range

ACKNOWLEDGEMENT

The auther expresses appreciation for the long collaboration of manufacturer Dainichi Kiko Co., Ltd. and the help in the beginning of Japan Abilities Corp.

ROBOTIC WRITING AND DRAWING SYSTEM FOR THE DISABLED

Steven J. King, Eugene Locke and David Cerundolo
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ABSTRACT - As a communication or expressive aid for the handicapped, the inverse differential kinematic equations of a Rhino XR-2 robot arm are used to enable a robot to write or sketch on a flat surface under joystick control.

RÉSUMÉ - On exploite les équations différentielles inverses de la cinématique du bras mécanique Rhino XR-2 pour qu'il soit possible, au moyen d'une simple manette, d'écrire ou de dessiner sur une surface plane à l'aide de ce bras. L'outil permettra aux handicapés de communiquer et de s'exprimer plus facilement.

INTRODUCTION

There are many disabled people whose artistic and expressive abilities are severely impaired because they do not have the motor skills necessary to successfully hold a pen to draw or write. The goal for the project presented in this paper, was to develop an interactive robotic drawing and writing system to restore these capabilities to the handicapped person.

The system is intended for use by someone of normal intelligence who lacks the normal amount of dexterity or eye-hand coordination. Employing this unit, operated with simple controls, the user can accomplish a desired sketch of some precision on a drawing surface.

In the design of this system, the following specifications were outlined as primary objectives:

1. The system should be easy to operate, and require little manual dexterity from the user. The set-up procedures performed by a fully capable helper should be kept to a minimum.
2. The system should have the ability to draw on virtually any height or angled surface within the robots work envelope.
3. Four different color pens should be available for drawing by means of simple selection controls.
4. The system should accept for its use a standard sized writing pen with no major modifications.
5. The user should have control over the writing direction, pen-up pen-down decisions, the angle of the writing plane, the pen color, and each of the motors separately.

The system which has been developed accomplishes the original goal and meets all of the above specifications.

HARDWARE

Five standard hardware items were selected for this project. These consist of a Rhino XR-2 robot equipped with optical encoders and microswitches, a Rhino XR-2 robot controller, an Apple II Plus microcomputer, an Apple joystick with two push buttons, and four Pilot medium point pens.

Two hardware items were developed for this project. The first one is a pen cartridge, machined from clear acrylic, for the robot pen interface. The pen slides inside the cartridge one and is held in place by a spring which provides an inch of passive compliance in either direction. This set-up allows the robot to be jerky in its motions while keeping an even pressure of the pen on the writing surface.

The robot's fingers slip into special grooves on the cartridge to hold the pen firmly. The grooves are beveled in such a way that the robot can be 3/8 inch off the center of the pen cartridge and still grab it successfully. See Figure 1.

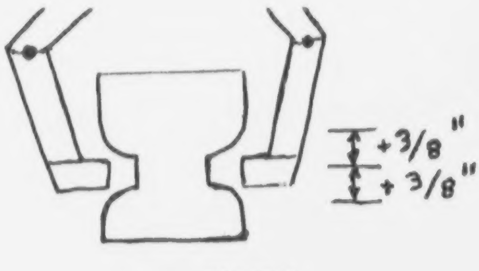

FIGURE 1

The second hardware item developed was a pen rack. The rack has holes for all 4 pens. The holes are machined into a conical shape so that the robot can be up to 3/8 inch off center, and still be able to slide the pen in the rack successfully.

WRITING/DRAWING

The Rhino robot has 7 degrees of freedom. These consist of a liner slide base, a waist, a shoulder, an elbow, wrist pitch, wrist roll and hand-open and closure (1). All writing motions are accomplished with the slide-base, shoulder and elbow joints.

The desired direction and speed of the writing movements are input to the Apple computer from the Apple joystick. The joystick provides values between 0,0 and 255,255. These are converted into changes in the X and Y, or X and Z axes. The change in the X and Y positions, dx and dy, are fed into Inverse Kinematic Equations (2) to deduce the necessary angular changes in the robots spherical joints to produce straight line motion. The Inverse Kinematic Equations are:

$$d\theta_1 = \frac{-1}{9 \cos \theta_2} \times [\sin(\theta_1 + \theta_2)\, dx - \cos(\theta_1 + \theta_2)\, dy]$$

$$d\theta_2 = \frac{-1}{9 \cos \theta_2} [-\cos \theta_1\, dx - \sin \theta_1\, dy]$$

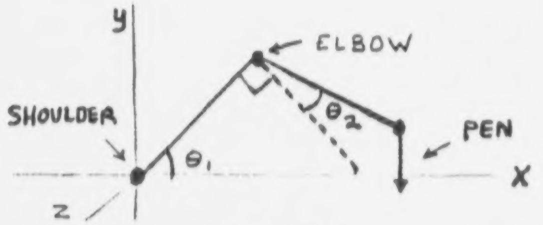

FIGURE 2

These angular changes are converted into encoder movements which the robot can execute.

Motion for the Z direction uses the linear slide base. Joystick values are converted into encoder movements directly.

The encoder movements are sent to the robot controller as ASCII strings. The controller sends signals to the robot and monitors the encoders till the movements have been accomplished.

Using Basic programming language, the speed of the robot is effected by the size of motor movement sent to it. For fast speeds, large movements are sent at one time. For slow speeds, a series of small movements are sent to the robot.

SELECTION CONTROL

Two selection screens are displayed at different times during the programs running. The first screen enables the user to choose pen colors, pen-up pen-down motions or writing plane angular changes by depressing one of the push buttons. The user can then choose the extent and direction of pen-up/down and angular plane changes with both push buttons, one for one direction, and one for the other.

The second selection screen gives the user access to each robot motor separately. A motor is selected by one push-button press, and then the direction can be controlled by pressing either push button for each of the directions.

CONCLUSION

The system which has been developed allows a person to use a robot to write or draw on any surface using joystick and push-button controls. The concept can be extended to use any type control the disabled person has at his disposal. It is hoped that such a system will provide an individual with an artistic or expressive outlet not previously available to them.

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ACKNOWLEDGEMENT

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PAGE TURNING SYSTEM UTILIZING A RHINO XR-2 ROBOTIC ARM

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ABSTRACT - Due to the need of the disabled who are unable to manually turn the pages of a book, a page turning system was developed. The design utilizes a Rhino XR-2 robotic arm interfaced to an Apple microcomputer. A bookstand has been developed which holds the book and retains the pages between turns.

RÉSUMÉ - Pour répondre aux besoins des personnes handicapées qui sont incapables de tourner à la main les pages d'un livre, un système tourne-pages a été mis au point. Il comporte un bras robot Rhino XR-2 interfacé à un micro-ordinateur Apple. Un support à livre qui immobilise les pages pour la lecture a été mis au point.

BACKGROUND INFORMATION

The development of a page turning device arises from the inability of disabled individuals to perform this task manually. With the aid of such a device, the disabled user can more freely and independently read a book or perhaps other printed material. Inadequacies with past products range from material to mechanical failure and poor designing, however, perhaps the strongest complaint arises from the number of "gadgets" that accumulate in the repertoire of the disabled. In the past, a single device was designed to perform a single task. It is the aim of this group to design a single process, and the necessary tools to implement it, rather than a single purpose "gadget." The design centers about a Rhino robotic arm controlled by an Apple microcomputer.

In order to answer these needs, certain guidelines were followed so that desired goals could be attained. The following is a description of design specifications:

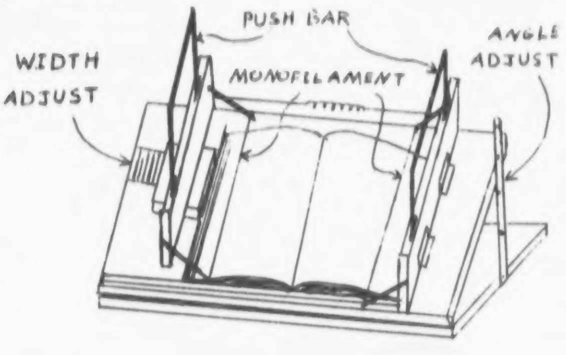
1. one page only - The most fundamental requirement of the page turning process is the ability to turn only a single page at a time.
2. forward/back turning - Back turning ability is important if the reader wants to refer to a previous page.
3. hold/unhindered view - The book must be restrained to prevent inadvertant page flipping without causing annoyance or hindrance for the reader.
4. reliability/repeatability - Reading almost any book requires hundreds or thousands of page turns, therefore durability and consistant precision is important.
5. delicate touch - Computer card reader rules apply. Pages must not be bent, folded, spindled, marred or mutilated.
6. universality - Utilization of the "process" concept. No permanent attachments to the robotic arm or manipulator. Tasks are to be implemented by the robotic arm with a specifically designed tool in the manipulator's grasp.

DESIGN SOLUTIONS

The Page turning system can be divided into three sections:

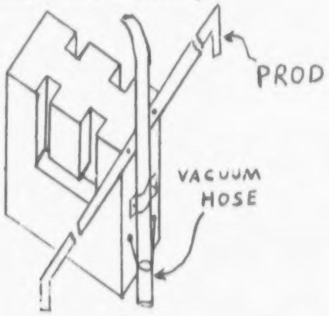
1. A base to hold the book open and pages down: According to publishers, books are designed to stay opened flat to a desired page. However, most new books are so tightly bound that pages flip according to their own temperament. Therefore, the design of a hold-down device which can keep the pages as flat as possible, allow a single page to be turned at a time, not obscure or hinder view and not cause damage to the pages is essential. In addition, it must be fully adjustable to allow different size books and to allow for different reading angles.

The top board size, 12" x 28", was designed to hold large books, and is adjustable by virtue of a sliding track on the left side. Pages are held flat by a clamp which consists of a monofilament cord stretched between protruding arms above and below the book forming pairs on each side. The monofilament unobtrusively lies across the margins of the book. Each clamp is hinged, enabling the monofilament to be raised when the page is picked up or deposited. Extending upward, at right angles and connected to each clamp are push bars.



2. The picking up of a single page: In order for the robotic arm to pick up a page, it must maneuver into position, hit the push-bar to raise the clamp and then pick up the page. In order to have the clamp raised before the manipulator moves into position, an extender or prod is required to hit the push-bar. Suction is used to pick up the page.

A tool was created which can be held in the manipulator's grasp. This tool consists of a grip block which has mounted to it the vacuum hose and the two prods. Two U-shaped finger slots were machined out of the grip block so the manipulator can grip the block more securely.



3. The translation of the page: Once the page is picked up, the Rhino robotic arm translates it over to the other half of the book. The Rhino is controlled by Apple II Basic. Two sections of software were developed for this project. First, a program enabling the user to teach the Rhino a series of moves. The second contains the main menu to which the user interfaces with the Apple. It also contains routines to access and execute steps produced by the first section. Along with these, there is a routine which takes into consideration the page thicknesses. After a specific number of pages are turned in one direction or the other, the routine will increase the number of steps needed to pick up the page. Every time a page is turned, a counter in that direction is incremented and another in the opposite direction is decremented. When the counter hits 50 turns, the program will add on 5 steps to the motor which enables the Rhino to pick up the page.

During the turning of the page, the suction does not need to be on all the time. The vacuum is controlled through software and a BSR remote controller. The program sends commands out to an interface card which is housed inside the Apple. This card interfaces to the BSR controller and on command will turn on or off the vacuum source via ultrasonic waves through the AC electric line.

CONCLUSIONS

The page turning system was designed, built and tested. The results were more than satisfactory. The robotic arm, with the designed page turning tool in its grasp will turn a single page at a time. If the reader wishes to review the previously turned page, the robotic arm will comply. The bookstand will retain a book to prevent inadvertant page flipping and does not hinder the reader's view. Use of the vacuum pick-up insures that the pages are handled with care. Due to the simplicity of the process and bookstand design, high repeatability and reliability are assured.

Future development on the page turning system may include:

1. Voice synthesizers/recognizers would ease the interface between the human and the Apple microcomputer.

2. Given a location, the Rhino may be able to find a book or put the book away.

3. A tool to turn more than one page would be beneficial so a person could start where he/she previously left off.

4. An interrupt system that would allow the user to interrupt the program at any time to possibly perform some other function.

Effective implementation of the page turning process has led to a universal and flexible design. This single process can become one of many process-tasks that can be assigned to the robotic arm in the future. The final result will be one single robotic arm with a complete repertoire of tasks it could perform to aid the disabled.

ACKNOWLEDGEMENT

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SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 9

INDEPENDENT LIVING III - ABILITY/SKILL ASSESSMENT/

VIE AUTONOME III - ÉVALUATION DES CAPACITÉS ET DES COMPÉTENCES

HISTOIRE DE JACINTHE

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ABSTRACT - Using a pathological prototype such as the osteosarcoma, this audiovisual document deals with a more humane approach to medical care. The various aspects of the malignant disease are reviewed, with some emphasis on post-amputation functional rehabilitation and return to family and social life.

RÉSUMÉ - En se servant d'un prototype pathologique tel l'ostéosarcome, ce document audio-visuel traite de l'humanisation des soins. Les différentes facettes de la maladie maligne sont revues et une certaine emphase est mise sur la réadaptation fonctionnelle post-amputation de même que sur la réinsertion socio-familiale.

Ce diaporama, d'une durée d'environ 16 minutes, est l'expression d'une certaine forme d'appréhension des équipes traitantes face aux multiples problèmes que génère la découverte d'une maladie maligne. Les localisations musculo-squelettiques sont lourdes de conséquences sur le plan fonctionnel en plus de soulever les mêmes problèmes fondamentaux que les autres systèmes. Qu'il suffise de rappeler les notions de sécurité et d'insécurité, d'espoir et de désespoir, de survie et de qualité de vie.

L'approche multidisciplinaire est-elle de nature à atténuer les inquiétudes que suscite un processus d'investigation complexe de même qu'un programme thérapeutique lourd en conséquences? C'est à cette problématique que tente de répondre le document. La réadaptation fonctionnelle, pour sa part, est analysée en fonction de la qualité de vie.

Cette réalisation constitue un outil de travail qui semble répondre vraiment aux besoins exprimés et permet aux intéressés de trouver ensemble les solutions aux problèmes vécus. L'histoire de Jacinthe transmet de l'information, de la sensibilisation ainsi que l'espoir nécessaire à la réabilitation du patient. C'est un document qui fait son chemin et nous anticipons son implantation dans les hôpitaux généraux ainsi que dans les maisons d'aide aux cancéreux où une utilisation adéquate porterait fruit sans doute.

Le personnage de Jacinthe est un personnage fictif servant de véhicule aux différentes situations ou expériences vécues par les malades. Cette étude permet d'identifier certains paramètres pouvant être appliqués à différentes situations quel qu'en soit le facteur causal: l'accident de travail, l'accident d'automobile, l'accident vasculaire vont à leur façon soulever des problèmes identiques auxquels les équipes traitantes auront à faire face.

L'objectif général du document est en définitive l'amélioration des conditions de vie des personnes atteintes d'une maladie maligne et la sensibilisation des personnes intervenantes à divers niveaux.

Une période de discussion et d'échanges entre les participants est prévue lors de la présentation.

EFFECTS OF POWERED MOBILITY ON YOUNG HANDICAPPED CHILDREN AND THEIR FAMILIES

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ABSTRACT - The impact of a powered mobility device upon neuromusculoskeletally handicapped two-to-five year olds and their families is evaluated. Standard measurements, odometer readings, daily and weekly logbook entries and data from a regularly administered driving test are collected. Initial results are presented.

RÉSUMÉ - L'incidence d'un appareil locomoteur motorisé sur les handicapés neuromusculosquelettiques de 2 à 5 ans et leurs familles est évaluée. Des mesures standards, des lectures d'odomètre, des entrées de journal quotidiennes et hebdomadaires ainsi que des données d'essais périodiques sont compilées. Les premiers résultats sont présentés.

Introduction

Independent means of mobility such as crawling, walking, and running are usually acquired in the first two years of life. These abilities and their development are often taken for granted. When neuromusculoskeletal disorders such as spina bifida, spinal muscular atrophy, and cerebral palsy prevent the timely emergence of these abilities the total development of the child is affected.

Developmental psychologists[1,2] have pointed out the crucial role that sensorimotor activity plays in the child's cognitive and psycho-social development. Mobility is an important element of the sensorimotor repertoire because it allows the child to seek out new experiences and return to safe and familiar places and persons. The lack of control over his/her own mobility compels a child to be dependent on parents or caregivers. This dependency can be expected to impact both the child and the parent or caregivers. The child is hampered in his/her development and the parents bear the physical burden of carrying or wheeling the child about.

At a very early stage of normal development a child acquires the general expectation that s/he can control his/her own behaviour as well as events in the world. Brinker and Lewis[3] call this the contingency experience. They assert that two reasons that place a handicapped child at risk for deprivation of the contingency experience are (a) motor disability, and (b) diminished expectations of parents and care-givers. Brinker and Lewis assert that the deprivation of contingency experience may lead to "learned helplessness" a condition in which the child has given up trying to control his/her world.

Over the past two years an evaluation has been conducted at the Ontario Crippled Children's Centre into the impact of provision of powered mobility to two-to-five year old children with neuromusculoskeletal disorders. Miniature Powered Vehicles (MPVs) constructed at the Centre[4] were provided to five boys and five girls whose ages at entry ranged from 1 year 11 months to 4 years 9 months with a mean age of 3 years and 2 months. Diagnoses of the children include Spina Bifida, Spinal Muscular Atrophy, Cerebral Palsy, and Quadrilateral Congenital Amputation. Subjects were selected who could operate a direct switching joystick.

Evaluation Objectives were directed both at the performance of the MPV and at the degree and type of activities that children engaged in as well as at the impact on children's families.

Specifically the areas of evaluation were:

(i) Usage of MPV inside and outside the home, odometer readings, types of activities performed and access gains.

(ii) Documentation of problems with the MPV, relating to seating, controls, breakdown, noise and potential or actual hazards.

(iii) Social development including peer interaction, independence, attitude change.

(iv) Impact on family such as supervision, ability to cope with and attitude toward the child's disability.

Many of these areas were evaluated using subjective judgements enhanced by questionnaires. Included are two standardized measures of the child's intellectual and developmental level, a semi-standardized physical assessment used routinely in the Centre, and a driving test.

Procedure

Subjects were seen by a team consisting of a psychometrist, technologist and therapist for an initial assessment, fitting, and parent interview, and at quarterly intervals thereafter. The study extended over a period of 18 months and subject entrance into the study was staggered.

The measurements obtained and their frequency of administration are listed below:

Measurements/observations	Frequency
Physical Assessment	Intake & 1/2 yearly
Parent Interview	
- Vineland Social Maturity Scale	Intake & 1/2 yearly intervals
- Dev. Profile II	Intake & Final
- Questionnaire	Quarterly Intervals
Logbooks	
- Daily Logbook	Daily

Measurements/observations	Frequency (cont'd)
- Weekly Logbook	Weekly
- Logbook Debriefing	Quarterly intervals
Record of average day of MPV use	Quarterly intervals
Driving Test	Quarterly intervals
Reported Problems	Irregular & quarterly
Technical Information	Ongoing

In the logbooks parents record use and activity patterns, odometer readings and aspects of control and supervision. The driving tests consist of five courses which measure typical driving skills, i.e. straight line, S curve, sharp left and right turns and backing up. The rest of this paper provides a selection of initial assessment data. A more complete discussion can be found in Lotto et al[5].

Results

The Developmental Profile II scale results in age-equivalence scores for different skill areas. The Physical Age of all subjects is an average of 58% (range 38% to 85%) below the chronological age (CA) and is in that respect similar to the Vineland Social Age. Self-help Age is below CA for all but one subject. Several of the other subscales show a more favourable outcome. Six out of the ten subjects achieved a higher than CA score on at least one subtest. Social Age and Communication Age are the subscales with highest scores for most subjects. These subtests appear, therefore, to depend less on the physical ability of the subjects assessed. Correlations between Developmental Profile and Vineland subscales are to be computed as well as correlations of relevant subscales with physical assessment outcomes and with other parameters of the studies.

Notable initial results of the logbook records are the percentage of days at which the MPV was used and which ranged from a low of 32% to a high of 92%. A greater proportion of indoor use of the MPV reflects the recording season (August to January). The maximum distance travelled in an 18 week period was 122.5 km. Control over the MPV was reported to improve steadily, a result that is confirmed by driving test data. As a consequence the amount of required supervision diminished accordingly. At the quarterly interviews parents were asked to report when the MPV was used, other than at home or school. Walks or hikes were cited most frequently (5x) visits to shopping malls, friends and relatives, parties, community events and finally going Trick or Treating were given as examples. The MPV was used regularly for play activities and hence for interaction with friends; was used to run errands once or twice a week, and frequently used to carry objects, for eating in, and watching television. These activities were carried out with minimal supervision. The MPV was also used for exploring with some supervision.

Parent Impact

One of the parent-impact questionnaires addressed the amount and frequency of aid and supervision that parents and siblings dedicate to the handicapped child (when not in the MPV). Three activities were focussed upon, and for all three activities, moving about the house, getting in and out of the house and playing, family members are involved to a large extent. Moving the child about inside the house (especially from floor to floor) falls mostly to the mother and less to the father; siblings are involved in these activities less often. The majority of children require total aid, that is, they must be carried about. For play the aid and supervision pattern is quite different. Here the subject and his/her siblings play a greater role than the parents and the amount of aid and/or supervision diminishes markedly.

A five point scale assessing agreements - disagreements with statements about parental feelings concerning their handicapped child presented a very divergent pattern of results. The spread of the scores, covering the entire gamut of the scale for four of the statements, is an indication of the vast differences in parental feelings that may be encountered. All parents view their child as maximally independent, three acknowledge that they are over protective and two parents deny this strongly. Opinions on vulnerability are spread evenly over the total scale, as are opinions about the sentiments of friends and neighbours.

Driving Test

When the driving test was initially administered there was one subject who was unable to complete any of the courses and eight out of ten subjects were unable to complete at least one of the courses. At the three-month interview all children tested have been able to complete all courses. The most obvious change that occurred to date has been in driver control as indicated by the results of the driving test. This finding corresponds well with those of Butler et al[6] who observed that eight out of ten subjects, 20 to 39 months old, achieved competence in less than three weeks.

Acknowledgements

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EVALUATION OF EARLY CENTRAL PROCESSING: APPLICATION TO THE PHYSICALLY HANDICAPPED CHILD

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ABSTRACT - Measurement of information processing in young children offers a valid, alternative method for assessing the cognitive status of the physically handicapped non-verbal child.

RÉSUMÉ - Une mesure du traitement de l'information chez les enfants constitue une nouvelle méthode valable pour évaluer l'état cognitif des jeunes handicapés physiques non verbaux.

Measures of information processing in infants and young children appear to provide a more valid estimate of current and future cognitive status than that obtained with sensory motor based protocols. (1-4) The Evaluation of Early Central Processing (EECP) assesses the child's capacity to process and assimilate complex sequential visual and auditory information with minimal reliance on gross motor behavior and speech. This paper describes the method, sets forth the results used to validate its diagnostic utility and describes its application to physically handicapped non-verbal children.

Method

The EECP is conducted in a darkened room equipped to resemble a puppet theater. The mother seated in a chair directly in front of the illuminated stage holds the child who is neither restrained nor coached during the course of testing. The occurrence and duration of such elicited responses as visual fixation, smiling, vocalization, pointing, turning to mother and fretting are recorded by hidden observers using button boxes connected to an 8 channel polygraph in an adjacent room. A cardiotachometer records beat to beat changes in heart rate that occur during the course of the 3 auditory and 2 visual test episodes that comprise the EECP. The individual presenting the test episodes is seated behind the stage curtains and indicates the onset and offset of auditory stimuli using a foot pedal that activates a stimulus marker on the polygraph. Electronic switches located in the devices used to present the visual test episodes activate the stimulus marker to produce an analog of the various components of the sequential visual stimuli. Thus each test episode produces a polygraph record that provides an analog of stimulus sequence together with a time locked recording of the child's behavioral responses and heart rate changes that are elicited during the course of testing.

Each of the test episodes conform to the same paradigm. An initial event, called standard, is repeated a fixed number of trials. These are followed by a moderately discrepant variation of the standard called the transformation that, in turn, is followed by the return of the initial sequence. There are 6 standards, 3 transformations, and 3 returns within each test episode.

The auditory episodes consist of speech phrases recorded using a tape loop that ensures comparable intonation and inflection as well as similar interstimulus intervals. The devices used in the 2 visual episodes are manipulated by the presenter who listens to a series of tape recorded commands that result in comparably timed presentations of the various components of the sequential visual stimuli. Each of the test episodes lasts about 4 minutes and the entire procedure requires 45 minutes.

Clusters of behavioral and heart rate responses are used to infer memory formation and recognition. While the composition of response clusters varies from child to child minimal criteria have been established to infer memory formation. Thus visual test episodes require sustained visual fixation, cardiac deceleration of 6 beats per minute or more, and the concomitant occurrence of 1 or more elicited responses such as pointing, vocalizing, and smiling. It is the first sequence within the standard transformation and return segments of the test episode that meet minimal criteria that is used to score that episode and to. infer the child's current level of information processing. Since the composition and number of presentations of the stimulus sequence within each test episode remains constant, the finding of reliable age related progressions in the infant's capacity to assimilate the initial presentations, the return of the previously experienced event, and finally the transformation segment suggests that the procedure is measuring those cognitive processes associated with memory formation as well as the rate of information processing over the first 3 years of life.

Standardization - Validation

The procedure was developed initially to monitor the cognitive status of a large sample (N=166) of normal children enrolled in a study of infant day care. Analyses of repeated observations obtained between 3½ and 30 months of age showed age related changes in response patterns and suggested that the procedure could be modified for use within a clinical setting to assess the cognitive status of young children presenting with a variety of developmental delays and physical handicaps. Modifications consisted of imposing a standard paradigm for presenting each of the test episodes and the use of clusters of responses rather than individual response measures to infer memory formation and recognition of previously experienced events.

The study used to examine the diagnostic utility and predictive validity of the EECP involved 44 children diagnosed as having developmental delays of unknown etiology. Typically these children had a prior history of slow motor development, showed significant delays in language learning, and manifested a variety of resistant, non-compliant behaviors. Age of entry was either 22 months (N=18) or 32 months (N=26). Although detailed medical evaluations failed to reveal any genetic or acquired disorder associated with mental retardation the average delays on the Bayley Mental Scales at the time of entry were 8 months and 11 months, respectively. The EECP was used to identify those children who were developmentally delayed yet cognitively intact from those who were developmentally delayed and cognitively impaired. The absence of any detectable organic disorder among the cognitively intact children led us to infer that their delays were experiential in origin and potentially remediable. In contrast the cognitively impaired group were presumed to have a central deficit in information processing that would not respond to environmental stimulation. All children received 10 months of parent implemented intervention directed primarily towards stimulating speech and language, increasing the sophistication of play behavior, and eliminating resistant, non-compliant behaviors. The Stanford-Binet Scales of Intelligence were administered at the end of the intervention phase and again at 6 and 18 months following treatment.

The results of the study showed that at the time of initial evaluation 34 of the 44 children had normal information processing ability. Of these, 14 were scoring at or above age level on the Stanford-Binet administered 6 months following treatment and at the 18 month follow-up the number had increased to 22. In contrast none of the 10 children with impaired information processing showed significant gains in their mental development and at the time of the 18 month follow-up had average delays on the Stanford-Binet of between 25 and 32 months.

The results confirm the growing belief that measures of information processing provide a more direct probe of underlying cognitive processes than sensory motor based developmental protocols. In addition, the EECP appears capable of identifying those children whose depressed performance on standard tests may result in an erroneous label of mental deficiency.

Application to the Physically Handicapped Child

The EECP has identified the presence of normal information processing abilities in children with cerebral palsy, meningomyelocele, and a variety of birth defects including congenital absence of arms and legs. In those cases where the physical disability did not preclude normal speech and language development the child's response to speech stimulation confirmed the accuracy of the EECP results. Our experience with the physically handicapped non-verbal child is limited yet the availability of a method that can identify normal cognitive potential in the non-verbal child coupled with the rapidly expanding technology in non verbal communication devices should markedly improve the treatment of the physically handicapped non-verbal preschool youngster.

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EFFECTS OF POWERED WHEELCHAIR MOBILITY ON SELF-INITIATIVE BEHAVIORS OF TWO-AND-THREE-YEAR-OLD CHILDREN WITH NEUROMUSCULOSKELETAL DISODERS

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ABSTRACT - Analysis of frequency of self-initiated interactions with objects, communications and changes of location observed in six children demonstrated that an early substitute means of mobility resulted in more active, initiative behaviour.

RÉSUMÉ - Des observations faites sur six enfants, qui avaient besoin et qui avaient reçu des voitures de malades car ils etaient très jeunes, ont révélé que de telles voitures ont beaucoup accru la capacité de prendre des initiatives.

Severely-restricted mobility during early childhood has long-lasting, deleterious effects. Lack of curiosity and initiative is a frequent result. Clinicians report the prevalence of passive, dependent life styles of persons with congenital motor-disability. Becker concluded from an extensive review of therapeutic restraint in medical treatment that "long-term physical restriction . . . during the neonatal, infancy or early childhood period can significantly alter and menacingly disrupt the entire subsequent course of emotional or psychological development in the involved child" (p. 239). Even well infants whose locomotion is intermittenly restricted from regular confinment to playpens or beds become apathetic. Moreover, they continue to lack curiosity when this practice is discontinued.

Theoretically, the inability to engage in successful mastery experiences in early childhood, many of which depend on locomotor ability, retards the development of self-initiative and achievement motivation leaving the child with a sense of helplessness. This feeling of helplessness tends to extinguish other mastery attempts. Overall activity level is reduced. Animal experiments have demonstrated that a pervasive sense of helplessness can be instilled in a relatively short time and is not reversible. Observational data from institutionalized infants also indicates that a sense of helplessness is learned by humans.

In the absence of ambulation, can a substitute means of functional mobility facilitate the development of more active, initiative behavior? Using a multiple baseline design across six subjects, three, two-hour observation periods in the homes were videorecorded at 10-day intervals before and after independent mobility was attained. Following baseline data collection, a specified level of proficiency was achieved during a training period by the subjects who were 23-39 months old. Each of the four girls and two boys passed the driving test in one to three weeks. While disabilities varied, all had severely-restricted mobility and normal intelligence.

Rates per minute of the natural frequency of three aspects of self-initiated behavior before (Phase A) and with independent mobility (Phase B) were plotted on semilogarithmic charts. Interactions with objects were coded when the subject intentionally made physical contact and took some action. Location changes (exploration of space) occurred when the subject traversed across six-foot-square areas by any means. Gestural or verbal communications were comments on objects or actions, and requests for objects, actions, or information.

Treatment effect was analyzed by observing change in the level of behavior, i.e., the number of data points falling above and below the mid-rate level of performance. Assuming no effect, distribution of data across phases would be equivalent. Magnitude of change was determined by comparing median scores of phases. Group results failed to support the research hypothesis that increased frequencies would be observed in all three aspects of self-initiative behavior for all subjects. The magnitude of change in spatial exploration was clinically important; all subjects showed increased changing of location with powered mobility, averaging a 1,350% increase over previous rates. Frequency of communications increased in four subjects but decreased in two for an overall increase of 15%. Interaction with objects decreased 29%, three subjects having increases and three having decreases. (The obtained t values were statistically significant at the p .05 level for changing of location.) Nevertheless, all the subjects improved in part.

Half did have increased frequencies in all behaviors. A 38-month-old girl with spastic quadriplegia, totally dependent for movement, became independently mobile in ten days. Change in experience with movement and space was most remarkable: changes of location increased 3,088%. Formerly, her play with the many toys provided by her mother was listless. In the wheelchair, interactions with objects increased 36% as she explored drawers and cabinets and helped her mother with household tasks. Communications increased 41%. Her parents felt that her increased activity level and heightened curiosity was dramatic. A 27-month-old girl with four-extemity limb reduction scooted on the floor, but she was generally passive and spoke infrequently. She seemed intimidated by the size, strength, and constant activity of her three-year-old brother who physically overwhelmed her in rough-and-tumble play. She cried vigorously but made no efforts to stop him or get away from him. With powered mobility, achieved in seven days, there was a 189% increase in changing location, 23% increase in interactions with objects, and a 22% in communications. She was assertive with her brother; chronic crying disappeared. Her parents said she was more curious and exploratory. A 35-month-old boy with myelomeningocele was an active child manipulating objects in play and crawling about slowly, but he had the lowest rate of communicating. With powered mobility, achieved in 17 days, changing of location and communications doubled. Rate of interaction with objects increased 58% as he found and explored novel objects not available at floor level. His mother commented, "His whole understanding of his surroundings has changed; he is getting into everything".

One child with myelomeningocele had increases in two aspects of self-initiative, but decreased in one. At 23 months, she seldom moved dragging herself short distances across the floor with great effort. She verbalized frequently and busily engaged herself with a rich variety of objects provided by her mother. In 14 days, she locomoted independently in her wheelchair. Although she continued to be busily involved with object play, frequency of interaction decreased 20%. Spatial experience changed drastically, however; changing locations leaped 10,350%. Communications increased 27%. Her parents described radical change in social behavior. Formerly shy and unwilling to be out of parents' arms, she played enthusiastically in her wheelchair at family gatherings and church school and initiated interactions with unfamiliar people.

Two children had increases only in changes of location. A 33-month-old with osteogenesis imperfecta, unable to even roll or pivot, was extraordinarily verbal and commanded his mother's almost constant attention with crying, tantrums, and demands to be nursed or carried. She provided a variety of toys which he actively manipulated in fantasy verbalization. An 11,500% increase in changing location occurred with independent mobility. Interaction with objects, however, decreased (58%) as did communications (40%). The latter was positive despite the hypothesis. Diminished talking and other demanding behaviors rendered him much more pleasant. This independence may have lessened his need for excessive physical and emotional contact with her. The last subject, 28-months-old, with arthrogryposis multiplex congenita, spent most of her time rolling about to touch objects on the floor. She, to a lesser extent, demanded her mother's attention with verbal banter. She passed the driving test in five days. Her mother, however, was quite anxious about use of the wheelchair. It crept when it moved and frequently stalled because the mother allowed only the slowest speed setting. Changes of location did increase, but only by 189%. She was physically unable to lift her arms to get objects herself. Her mother refused to give her toys while she was in the wheelchair. Not surprisingly, interaction with objects decreased 88%. There was a 15% decrease in communications; observers perceived there was less verbalization to command attention.

There are several possible explanations for the unexpected decreased behaviors. Although powered wheelchairs allowed access to more of their environment and at a new level, the subjects were restricted to objects which could be reached from the wheelchair. The child with the greatest decrease was further restricted because she could not reach for objects at all and her mother did not make toys available. The subjects in whom communications decreased were the most physically restricted, the most vocal, and the most demanding. It is possible that increased independence through locomotion lessened need for control though speech. Another explanation may be that the achievement of locomotion temporarily depresses interest in communication and objects in some children. There is no research with which to compare these results.

Involved families were convinced that powered mobility had a favorable impact upon their child's behavior. Safety was not a problem; the children were skillful and responsible drivers. Concern, expressed by some, that an easy means of mobility might diminish motivation for ambulation was unfounded. Instead, the children manifested unprecedented movement of other forms (i.e., riding a rocking horse or pushing a tike bike).

While offering tantalizing insights into possible contributions of mobility, this study provides only preliminary data. The sample size was small and the observational phases were minimal. Aspects of development not addressed in this study appeared to be affected (e.g., peer interaction). Alterations in patterns of parent-child interaction seemed to occur. Several parents stated that they felt and acted differently toward their child, particularly as regards more normal expectations and discipline. In future designs, more subjects and extended observation phases are needed to determine longer-range effects. Phases allowing intervention by the researcher to make the environment more wheelchair accessible or to help parents promote physical independence should be included.

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AN OBJECTIVE EVALUATION METHOD OF HIGH CORTICAL FUNCTION (UNILATERAL SPATIAL AGNOSIA IN POST STROKE PATIENTS)

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ABSTRACT - The aim of this study is to develop an objective evaluation method for visula-spatial agnosia secondary to CVA. Microcomputer-base system was built and tried for clinical use. It was found out to be comparable with other clinical tests.

RÉSUMÉ - Le but de cette étude est de mettre au point une méthode d'évaluation objective pour l'agonosie visuelle spatiale consécutive à un accident cérébro-vasculaire. Un système à base de microordinateur a été mis au point et des essais ont été réalisés dans le domaine clinique. Les résultats obtenus étaient comparables à ceux que donnent les autres tests cliniques.

Disorder of high cortical function in cerebral vascular accidents is one of the most important factors to limit the rehabilitation potentials. However, the evaluation method of these disorders have not been established yet. The aim of this study is to develop an objective evaluation method for measurement of unilateral spatial neglect with using the microcomputer (OKI IF 800 - CPU Z80B) as the main data processing device.

EQUIPMENTS : The system is consisted of a digitizer-pen unit, the touch board which was specially made for this study and the pins-board, both of which are electrically connected to show the locations of targets (Photo. 1).

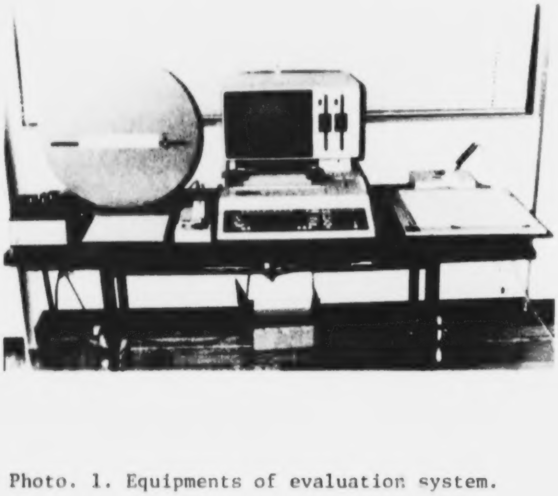

Photo. 1. Equipments of evaluation system.

VISUAL GALCULATION TEST (VCT):Test paper (26X26cm) is placed on the digitizer. Subjects have to mark the round targets with the pen on the paper which is composed with 4X4,6X6 and 8X8 lattices in each. Several test patterns are prepared including the patterns with noise (Fig.1.).

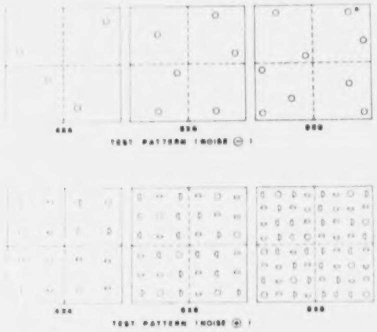

Fig. 1. Test patterns of VCT.

Results are obtained with orders of targets marked (searching processes), consumed total time, and missed points (Fig. 2.).

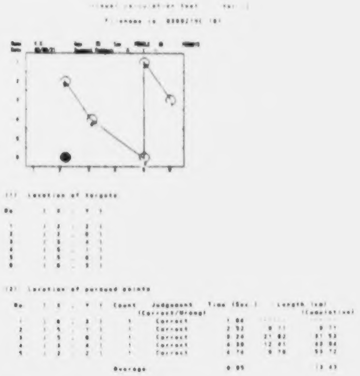

Fig. 2. Example of VCT output.

DRAWING TEST (DT) : First, cube drawn on the paper is shown to subjects. Test paper in which 3 of 9 lines are drawn is given to be completed for cubic form. (Fig. 3)

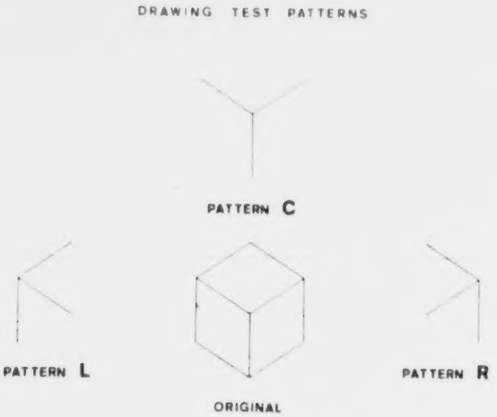

Fig. 3. Test patterns of DT(Drawing test).

Test results are obtained as follows.

1. The drawing process with optional time intervals (sec). (Fig. 4)
2. Consumed time.
3. Distorted figure of drawing.

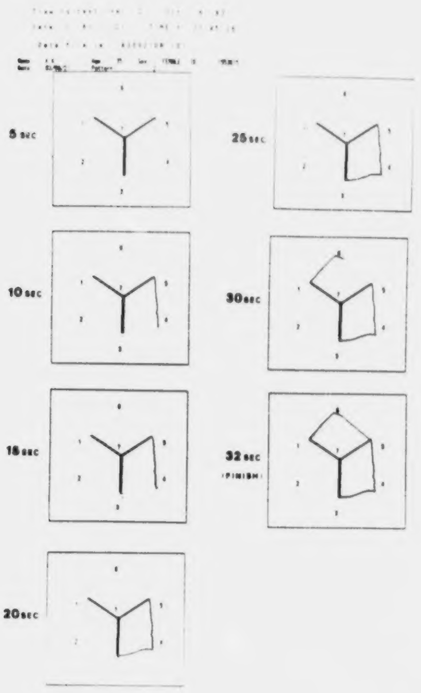

Fig. 4. Example of DT output.

RESULTS : Patients with CVA were selected for these tests. Tests were repeated with 1 to 2 week intervals Those who had unilateral spatial agnosia were observed in the recovering processes and following results are obtained.

In VCT, missed points were reduced and consumed time is reduced as well. In DT, distortion of drawn form was lessened and time was reduced. Various agnosia tests were compared. Our tests were found out as the sufficient tests enough for the clinical tests.

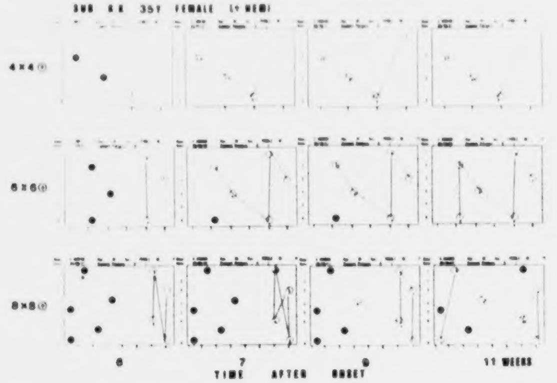

Fig. 5. Repeated VCT evaluation of a post stroke patient with agnosia.

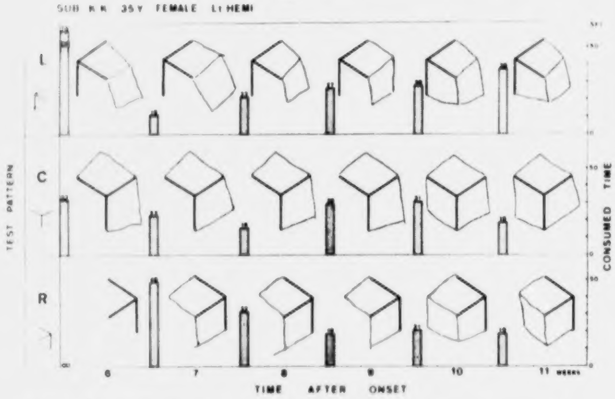

Fig. 6. Repeated DT evaluation of a post stroke patient with agnosia.

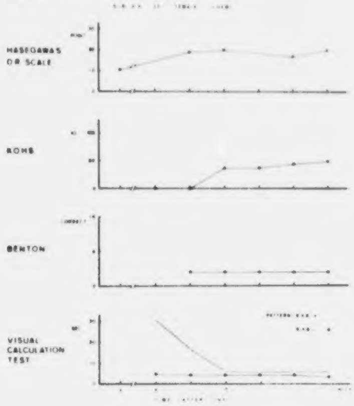

Fig. 7. Comparison of various agnosia tests.

PERTINENCE D'UNE INTERVENTION CONJOINTE EN ERGOTHÉRAPIE ET EN ACTIVITÉ PHYSIQUE EN VUE D'UNE INTÉGRATION DE LA PERSONNE HANDICAPÉE À L'EMPLOI

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RÉSUMÉ - Ce processus de mise en forme est composé de simulations de gestes de travail et d'un programme d'activités physiques, facilitant le retour à l'emploi. Il est basé sur l'analyse de tâche selon les cinq dimensions du mouvement répété et l'évaluation de quatre paramètres reliés à la condition physique.

ABSTRACT - Work gesture simulations and a program of physical activities compose this physical training process, which aim is to facilitate work integration. It is based on a task analysis according to the five dimensions of repeated movement and the assessment of the four parameters of physical fitness.

Suite à une période plus ou moins prolongée d'inactivité et lorsque la rééducation fonctionnelle est terminée, l'individu dont les capacités physiques sont insuffisantes pour réintégrer le marché du travail peut bénéficier d'un processus d'amélioration de la condition physique et faciliter ainsi son retour à l'emploi.

Du point de vue fonctionnel, la condition physique consiste en la capacité à accomplir les tâches quotidiennes avec vigueur et promptitude, sans fatigue excessive et avec suffisamment d'énergie pour jouir pleinement du temps consacré aux loisirs et rencontrer les situations d'urgence. Le programme d'activités élaboré conjointement en ergothérapie et en activité physique vise l'optimalisation de cette définition.

En ergothérapie, les exigences de l'emploi retenu seront reproduites le plus fidèlement possible par des simulations de gestes de travail. Pour ce faire, une description détaillée de l'emploi s'avère essentielle. Cette dernière peut être tirée de la Classification Canadienne Descriptive des Professions. Par la suite, les divers mouvements impliqués sont analysés et leurs caractéristiques déterminées sur la base des cinq dimensions du mouvement répété. Par définition, un mouvement répété est l'ensemble de gestes articulés, provoqués par une activité musculaire, visant à produire une action déterminée dans le temps et l'espace et possédant un certain caractère répétitif.

Les cinq dimensions du mouvement répété peuvent être ainsi définies:

- Nature: l'ensemble des caractères de l'activité.
- Forme: schème d'exécution adopté pour le mouvement.
- Intensité: exigences énergétiques du travail.
- Durée: temps actif consacré à l'exécution du mouvement ou de la tâche.
- Fréquence: périodicité du mouvement durant une période de temps déterminée.

L'analyse de tâche étant complétée, les activités requises afin de reproduire les exigences de l'emploi sont alors déterminées. Tout au long du processus, les activités sont graduées en fonction des cinq dimensions du mouvement répété.

En activité physique, quatre paramètres reliés à la condition physique sont généralement mesurés avant d'établir le plan d'activités. Il s'agit de la puissance aérobie, la graisse corporelle, la vigueur musculaire et les indices spécifiques à l'emploi.

L'appréciation de la puissance aérobie s'effectue par la mesure ou l'estimation de la consommation maximale d'oxygène. Cet indice de la condition physique revêt une importance particulière lors de l'exécution de tâches exigeant une dépense énergétique élevée. Sa mesure s'effectue à l'aide d'une épreuve d'effort sous maximale ou maximale sur bicyclette ergométrique, tapis roulant ou manivelle.

Selon plusieurs physiologistes, un individu ne peut effectuer efficacement une tâche, sur une période de temps prolongée (3-4 heures), si la dépense énergétique requise est supérieure à 40 ou 50% de la consommation maximale d'oxygène. L'évaluation précise de la tâche selon les cinq dimensions du mouvement répété permet d'exprimer avec plus de justesse le pourcentage critique de la consommation maximale d'oxygène à ne pas excéder. Chez l'adulte de trente ans, cela correspond à une élévation de la fréquence cardiaque aux environs de 120 à 130 battements/minute.

L'estimation de la quantité de graisse corporelle est un déterminant important de la condition physique. Une quantité excessive de tissus adipeux a pour conséquence une augmentation de la tension sur les membres inférieurs et sur les structures articulaires de la région lombaire. On reconnaît que la tension artérielle et la fréquence cardiaque pour une tâche particulière sont plus élevées chez les obèses que chez les individus ayant un poids normal. Conséquemment, une plus grande fatigue générale et une efficacité moindre sont observées pendant le travail. Le pourcentage de graisse s'estime par la technique de densitométrie. La densité corporelle peut être obtenue par la méthode utilisant la pesée hydrostatique ou celle utilisant la mesure des plis cutanés.

La vigueur musculaire s'apprécie selon deux composantes: la force et l'endurance. La force musculaire fait référence à la capacité d'un muscle à produire le plus de tension possible lors d'un effort maximum. Le développement de cette qualité est lié en partie au volume du muscle et au contrôle neuro-musculaire exercé sur celui-ci.

L'endurance musculaire fait référence à la capacité d'un muscle à produire une tension d'intensité faible à modérée sur une période de temps prolongée. Le développement de cette qualité repose grandement sur l'irrigation sanguine locale à l'intérieur de la musculature sollicitée. Dans l'accomplissement des tâches de travail, l'endurance musculaire prédomine lors de l'exécution de tâches à caractère répétitif tandis que la force musculaire est nécessaire lors de la manipulation d'objets lourds.

Enfin, la spécificité de chaque emploi exige que certains indices spécifiques sont identifiés pour toutes les tâches reliées à cet emploi. Par exemple, le travail de pompier demande une adaptation rapide de la fonction cardiaque. De même, l'équilibre et la coordination oeil-main sont deux indices spécifiques nécessaires à l'exécution de ce travail, surtout lorsqu'effectué à plusieurs mètres du sol. Plusieurs tests sont élaborés afin de reproduire le plus fidèlement possible les conditions de travail et de mesurer les différents indices spécifiques.

Après avoir évalué le niveau de condition physique du bénéficiaire selon les paramètres précités, le plan conjoint d'activités est établi en ergothérapie et en activité physique en fonction du niveau de condition physique et des exigences de l'emploi.

La consommation maximale d'oxygène peut être augmentée significativement par des activités sollicitant des masses musculaires importantes telles la bicyclette, la natation et le jogging. Ces mêmes activités ont aussi un effet à long terme sur la graisse corporelle. L'organisme peut donc fournir une dépense énergétique plus élevée et conséquemment un travail physique plus important.

Les effets d'entraînement sur la vigueur musculaire sont variables. Ainsi, un entraînement approprié pourrait doubler la force d'un muscle à long terme, tandis que l'endurance pourrait être augmentée dans une proportion de 500% pour certains groupes musculaires.

Somme toute, malgré certaines limites, un plan d'intervention conjoint en ergothérapie et en activité physique s'inscrit adéquatement dans une démarche d'intégration de l'individu présentant un handicap physique. De plus, l'ensemble des paramètres reliés à la condition physique sont des indicateurs utiles qui permettent d'évaluer avec plus de précision la capacité d'un individu à exécuter une tâche particulière.

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SET: A SKILL EVALUATOR AND TRAINER FOR PEOPLE WITH DISABILITIES

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ABSTRACT - This paper describes a device to assess and train the abilities of physically disabled people to operate assistive equipment. The Skill Evaluator and Trainer (SET) is a portable, lightweight, microprocessor-based device. It has proven of value in both assessment and training of skill and it has found good acceptance by clients and therapists.

RÉSUMÉ - Cette communication décrit un dispositif visant à évaluer et améliorer l'aptitude des personnes souffrant de handicaps physiques à utiliser diverses aides. Le Skill Évaluation and Trainer (SET) est un dispositif portatif et léger utilisant un microprocesseur. Il s'est avéré utile pour l'évaluation et l'amélioration de la compétence et a été bien accueilli par les clients et les thérapeutes.

INTRODUCTION

There are now a large number of interfaces available by which disabled people can control electrically-operated assistive equipment (1). They are often interchangeable as connection formats are becoming more standardised (2). The need for comparative testing of controls and control sites to operate assistive devices has been recognised and assessment tools are being developed (3,4). The Skill Evaluator and Trainer (SET) was designed to provide a means of objectively measuring skill in the operation of a control interface and subsequently training for improved skill (5).

DESCRIPTION

The SET is a device which presents stimuli and records the speed and accuracy of responses using any of a range of plug-in interfaces (Figure 1). It weighs only 6.5 kg and is housed in an attache case measuring 46 cm X 32 cm X 12 cm. The stimulus is displayed on an 11 X 11 matrix of red light emitting diodes (LEDs) covering an area 18 cm X 18 cm. The stimulus may be a 3 X 3 square of LEDs or an arrow, depending on the task and the interface under test. The subject's response is indicated by a pattern of yellow LEDs. When red and yellow LEDs match for a pre-set time the trial is complete.

OPERATION

In operation, the therapist or experimenter chooses an interface and mounts it at an appropriate control site for the subject. Four switches on the control panel need to be set:

1 the type of interface to be tested,
2 the number of stimulus presentations in a run,
3 the time required for the response (yellow LEDs) to match the stimulus (red LEDs), and
4 the pause time between a successful match and the presentation of the next randomly selected stimulus.

When the 'restart' button is pressed and released the first target appears and the subject has to operate the interface to make the yellow LEDs match the red target LEDs as quickly and accurately as possible. When the selected number of targets have all been matched for the required match time, the LED display in the attache case indicates the total time for the disabled person to match all targets and the number of errors made. If a printer with a standard Centronics interface is connected, a detailed summary of results is printed for each target.

NEED FOR THE SET

A survey was carried out in 1982 of the electrically-operated assistive devices used by the 173 students attending the Regency Park Centre. It was found that nearly one third (54) of the students used at least one electrically-operated device other than an electric typewriter, indicating the need for an objective procedure for selecting the optimum interface for each user. The use of electrically-operated devices has increased since that survey.

FIELD TESTING

In order to test the performance of the SET outside the laboratory, to develop a procedure for using it and to demonstrate its ability to discriminate between interfaces, it was used with able-bodied children ranging in age from 6 to 12 years at a local school. The SET showed mechanical and electrical reliability, it satisfactorily discriminated between alternative wheelchair control interfaces, and it could be used with children as young as 6 years.

2-STATE SWITCHES

A study was carried out to establish the value of SET in selecting an appropriate 2-state switch for young people with cerebral palsy. Up to 6 alternative switches were evaluated with 4 subjects using their favoured anatomical site. In all cases the fastest switch was one previously in use. It was concluded that the SET can be used to evaluate 2-state interfaces but that the interfaces are so simple that a number are almost equally fast and patient preference should be an important determinant of choice.

WHEELCHAIR CONTROLLERS

A study was carried out to evaluate the use of the SET in selecting between alternative wheelchair controllers. The subjects were boys with Duchenne muscular dystrophy. When SET results were compared with performance on a wheelchair slalom course, it was concluded that the SET is a valid indicator of actual wheelchair performance.

DISCUSSION AND CONCLUSIONS

In addition to the initial field testing on able-bodied children and the clinical evaluation using 2-state switches and wheelchair controllers cited above, the SET has been used with another 17 patients who were referred for assessment of whom 10 underwent further training to improve their skills.

Most referrals are for assessment of wheelchair controllers. The SET is particularly valuable as an assessment and training device to improve performance with a wheelchair controller without having to suffer the consequences of errors. In this respect it functions in much the same manner as an airline pilot's flight simulator.

The SET has proven to be readily accepted by therapists as an assessment and training tool. A manual has been prepared for it. The manual and the SET are available for purchase.

ACKNOWLEDGEMENT

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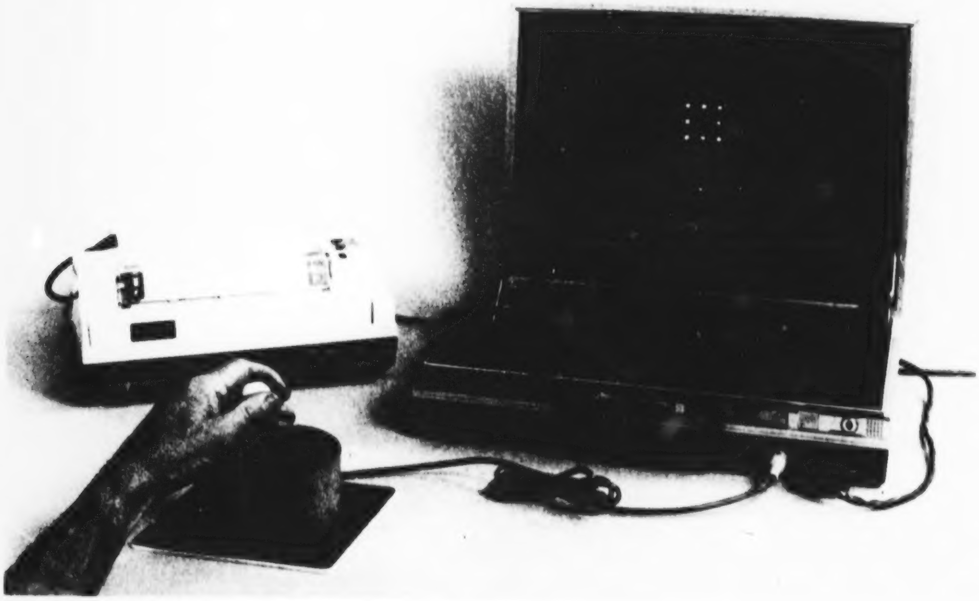

FIGURE 1 - The Skill Evaluator and Trainer (SET) with proportional joystick interface connected and optional printer attached.

NEW TECHNOLOGY IN PATIENT ASSESSMENT: THE RELIABILITY AND VALIDITY OF THE MYOMETER IN MANUAL MUSCLE TESTING

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ABSTRACT - A three part experiment was performed to investigate the reliability and validity of the myometer as an adjunct to manual muscle testing. The results showed significant reliability and validity at the .01 level for single tester assessments.

RÉSUMÉ - Une expérience à trois volets a été réalisée dans le but d'étudier la fiabilité et la validité du myomètre comme complément aux essais manuels des muscles. Les résultats indiquent une fiabilité appréciable et une validité de l'ordre de 0,01 dans les évaluations à un seul essayeur.

INTRODUCTION

One of the limiting factors in the rehabilitation process is the ability of the clinician to assess the needs of the patient. When assessing a patient it is important to outline specifically what tasks the patient wants or needs to perform and the criteria for successful performance of these tasks. In general, successful performance of the tasks of daily living depends on the ability of the musculature to produce moments of force across skeletal joints and the ability of the neuromuscular system to control the temporal aspects of these moments of force. Thus, when an individual has difficulty performing an important task, the first question that must be asked is; Was it a lack of strength or a lack of motor control that caused the inadequate performance. An appropriate strategy for intervention can not be derived without the answer to this question. This paper addresses the everyday problem of assessing muscular ability (strength) validity and reliabilty within the constraints of the clinical setting.

Historically, muscle force production capability has been assessed subjectively using manual muscle testing techniques. The subjective manual muscle test requires the therapist to grade (estimate) static muscle strength on a five point ordinal scale (Colthurst and Falconer 1981). While the reliability of the subjective strength scores is good, the sensitivity and validity of subjective strength estimates are poor at best. Clearly, muscle strength testing is an area where it is appropriate to invoke some form of technology to produce measures that are valid, reliable and adequately sensitive to changes in strength levels.

In 1981, a objective manual muscle test was introduced by Helewa, et al. Their protocol involved the use of a modified sphygmomanometer which monitored the pressure applied to the patient by the therapist during the manual muscle test. The sphygmomanometer pressure readings were found to be reliable under a variety of test conditions and it was concluded that the device provided a much improved means of assessing muscular strength (Helewa, et al., 1981).

It is important to note that Helewa et al. (1981) reported that a cubic polynomial transformation was necessary to convert sphygmomanometer pressure measures back to actual muscle force. The relationship between sphygmomanometer pressure and contact force applied is also dependent on variables such as the shape of the patient and the size of the therapist's hand. Thus, the high precision, pressure data only provides a rough ordinal index of muscle strenghth. Therefore, the application of technology in the case of the sphygmomanometer has not resulted in a significant improvement in the quality of information received by the clinician.

From an engineering design point of view, it is desirable to have technology take the responsibility for validly collecting the data, processing it and presenting it to the clinical practioner in a stable, usable form. The idea is to use the human as a diagnostician, not as a transducer or data processing tool. To this end, a new device called a myometer has been developed (Penny and Giles, Christchurch, U.K.). The device houses a high precision force transducer with electronic circuits (peak detector, sample and hold and analog to digital converter) that drive a liquid crystal display. While the myometer has much theoretical support, it's routine use in rehabilitation clinics is not justified until the reliability and validity of it's measures have been assessed and fully documented.

The purpose of this study was to investigate the reliability and validity of the myometer as an adjunct to manual muscle testing in clinical rehabilitation. The study was performed in three parts:

PART A - The reliability and validity of the force transducer and electronics;
PART B - The reliability of myometer strength measures in healthy young adults;
PART C - Concurrent validity of myometer, sphygmomanometer and subjective strength assessments in patients with rheumatoid arthritis.

METHODS

PART A: A special device was built that allowed a number of weights to be placed directly over the force transducer of the myometer. A set of 30 one kilogram massess (weighed to the nearest tenth of a gram) was used first to calibrate the myometer (tune the offset and gain) and then to assess it's validity (linearity, hysteresis) and reliabilty (repeatability of measures over time). One trial consisted of placing the weights on the myometer one at a time and then taking the weights off one at a time (reading the display every time a weight was added or removed). Five trials were performed for each of four myometers per test session. The test session was repeated after one day, one week and one month.

PART B: Four testers and twelve subjects were recruited from a second year physiotherapy class (University of Toronto). The testers were previously trained in manual muscle testing and were given instructions and practice using the myometers. The test muscle group for this part of the study was wrist extensors. Each tester performed ten strength tests (with a myometer) on each of the twelve subjects on two separate days.

PART C: Three testers (registered physiotherapists) assessed the strength of wrist extensors and knee extensors in each of six subjects. The subjects were patients undergoing active treatment for rheumatoid arthritis in the Rheumatic Diseases Unit, The Wellesley Hospital, Toronto. Each therapist performed fifteen manual muscle tests on both muscle groups of each patient. The fifteen tests included five subjective tests, five sphygmomanometer tests and five myometer tests. These tests were performed within (ie. spread out over) an hour and a half to minimize subject fatigue, but also to avoid confounding the results with strength changes over time (due to the chemotherapy the patients were on). The order of testing in terms of therapists and devices was fully randomized.

RESULTS

PART A: The relationship between the known force inputs and the myometer display output was highly linear (worst case non-linearity of 1 percent). Hysterysis was less than 1 percent of full scale. The lowest Pearson product moment correlation coefficient relating the known input to the measured output per trial was 0.9997. Two way analysis of variance showed no significant difference in calibration coefficients between devices or between sessions.

PART B: A three way analysis of variance showed significant differences in strength scores between subjects ($p > .01$) and between testers ($p > .01$) but no significant difference between sessions.

PART C: There were two muscle groups (wrist extensors and knee extensors) and two devices (myometer and sphygmomanometer), so four separate two way analyses were performed. In all four analyses there were significant differences found between testers and subjects at the .01 level. Mann-Whitney U tests were performed on the subjective manual muscle test results. Multiple tests revealed no significant difference between any of the testers for either muscle group (wrist extensors and knee extensors). Concurrent validity was assessed by correlating subject-tester cell means between testing techniques. Pearson product moment correlation coefficients were used to correlate myometer and sphygmomanometer strength scores. Spearman-Brown rank order correlation coefficients were used to correlate the myometer and sphygmomanometer test scores to those of the subjective test. The analyses showed that the myometer, sphygmomanometer and subjective scores were significantly correlated at the .05 level of significance.

DISCUSSION

The results of PART A established that the transducer and electronics in the myometer are both valid and reliable for measuring forces up to one month following calibration.

The results of PART B showed that the testing protocol used with the myometer was sensitive enough to find the expected differences between normal young adult subjects. The fact that there was no significant difference between test sessions indicates that the test protocol is highly reliable. The large differences found between testers indicate that a single tester environment is necessary for manual muscle testing with a myometer. In PART C the results showed a high degree of concurrent validity between strength tests performed 1) subjectively, 2) with a myometer, and 3) with a sphygmomanometer. This verifies that all three forms of the manual muscle test do measure (or estimate) the same thing even though the non-myometer tests produce inferior quality (ie. ordinal scale) data. As in PART B, the results indicate that a single tester environment is necessary to guarantee the reliability of results obtained by both myometer and sphygmomanometer. The rehabilitation clinic is almost always a multiple tester environment, so special care must be taken to ensure that the same tester performs all tests on a given patient. It is interesting that there was no significant difference found between testers for subjective manual muscle testing. It is felt, however, that this increase in reliability is simply a reflection ofthe lack of sensitivity of the five point ordinal scale used in subjective testing.

In summary, the myometer has demonstrated significant reliability and validity for single tester manual muscle testing. Multiple tester environments will significantly reduce the reliability of test scores. A high degree of concurrent validity was shown between myometer results and two other forms of manual muscle testing. It is concluded that the myometer will provide a significant improvement in the quality of information obtained from a manual muscle test.

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SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 10

WHEELCHAIRS II - CONTROL SYSTEMS AND POWER DRIVES/
FAUTEUILS ROULANTS II - SYSTÈMES DE COMMANDE ET MOTORISATION

MODULAR DESIGN FOR POWERED WHEELCHAIRS

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ABSTRACT - The advantages of constructing powered wheelchairs from a collection of functional modules is discussed, with special attention paid to increased serviceability and greater ease of customization. A specific vehicle constructed in such a fashion is discussed in detail.

RÉSUMÉ - On discute les avantages de construire un fauteuil roulant motorisé à partir d'un ensemble de modules fonctionnels, en accordant une attention particulière à une plus grande facilité d'entretien et d'adaptation. On discute en détail d'un véhicule particulier construit de cette manière.

The Wheelchair III conference of 1982 had as one of its major results the promulgation of the notion of a powered wheelchair consisting of a power chassis and a separate seating system in order to maximize the customizability of wheelchairs for persons with severe disabilities. RRD has pursued subsequent wheelchair design work with this paradigm in mind, and even furthered this trend of thought by designing one of their machines as a collection of functional modules.

One of the major problems with powered wheelchairs is the difficulty and expense involved in repairing them after they have failed either mechanically or electrically. The most commonly used style of powered vehicle has motors and gearboxes that are specifically for either the left or right side of the vehicle. When one of these motors fails, it must be replaced by an exact duplicate part, which is often difficult to obtain quickly (dealers can't afford to stock these expensive parts). This often leads to long vehicle downtimes, with the associated loss of mobility, or the ownership of one or more spare vehicles (an expensive proposition at best).

Even when parts are available, the method of construction is such that it does not encourage repairs to be performed by other than qualified (and consequently expensive) servicemen. This is particularly a problem when the owner of the vehicle chooses to live away from easily accessible wheelchair service facilities.

Another issue that should be addressed is the difficulty involved in customizing a vehicle to meet a specific individual's needs. the situation is largely "one style fits all". Heavily customized, or even custom vehicles exist, but are a rare and expensive breed, inasmuch as they require either extensive adaptation of existing equipment, or the manufacture of custom electronics and motor packages, a prospect even more expensive than modification. This problem is particularly acute in the field of powered vehicles for children, whose needs are often difficult to meet with even a child-sized conventional chair (hence the proliferation of special vehicles for little ones; witness those from the Ontario Crippled Children's Hospital, Stanford Children's Hospital, etc.)

Clearly, there is a need for a personal vehicle that is easily and cheaply serviceable, and readily customizable for the individual user, both mechanically and electronically. The engineers at Rehabilitation Research and Development Center were aware of this need, and have met with some success in their attempt to address it in the design of their Alexis Wheelchair Technology Testbed. This vehicle was designed as a collection of functional modules, nearly all of which could be used in some application other than the one they were initially intended for, making the assembly of other types of vehicles from these components possible, and potentially very simple and inexpensive.

When designing a system of functional modules to perform a given task, one must first decide how to divide the task into useful parts. For example, it would not be useful to define "mobility device" as a functional module in this instance: the result would be a module that consists of a complete powered wheelchair. A more effective approach is to break the powered vehicle down into manageable chunks by adopting a generic paradigm of the operations that are necessary in such a vehicle. We have decided to divide powered mobility aids into the following functions: the command acceptor, a logic section, amplification, actuation, chassis, suspension, energy storage and seating. It's important to note that these "parting lines" are arbitrarily chosen, and are not necessarily the only way that such a machine can be divided up.

Once a design paradigm has been adopted, the designer must define how these functions will be mapped onto his functional modules. Will there be a separate module for each function? Should the command input and the logic be integrated into one module, or should logic and amplification be one module? In the case of the EJ 3P, all three functions are closely integrated in essentially one box. the joystick provides a current dividing function that could be said to be part of the analog logic section, and the logic section is housed in the same box as the amplification section. Again, how one chooses to divide the functions among the modules is arbitrary, and depends on the designer's philosophy. How should these devices work together? Should a standardized generic connection be established to allow, for example, different logic units to operate with the same amplifier?

In the our case, the modules evolved as part of an entire vehicle, and were developed in a parallel fashion, that is, all the pieces of the machine were designed pretty much at the same time by a small group working very closely together. It consists of a command interface, a programmable logic section, a set of independent single actuator amplifiers, and a set of independent motor drive units. All of the amplifiers are identical, as are the drive units, this allows the parts to be interchanged, and would result both in lower inventory costs for the manufacturer and service centers, and in lower manufacturing costs because of the larger production runs possible. Further, these components could be assembled in a variety of different ways, with only minor changes to the controller to account for the resulting geometric configuration.

DRIVE UNITS

The drive modules consist of a power amplifier, a 1/10th horsepower flat-wound "pancake" motor, a reduction gearbox and a wheel support assembly (bearings, axle, and hub). The unit requires 24V input from the vehicle batteries, one logic line to select direction of rotation (two if regenerative braking is desired) and a speed command. This speed command presently takes the form of a Pulse Width Modulated square wave, but could as easily be an analog signal with only a small change in the power amplifier circuitry. The module outputs physical motive power, and optionally a tachometer or shaft encoder signal for use in feedback applications. The frame that provides structural support for these devices is 10 inches tall by 6.5 inches wide, the prototype unit without axle and wheel assembly is less than 6 inches deep, and could be substantially thinner in a production design. A device this size could easily be incorporated in a custom vehicle design, it is even attractive in that the device doesn't limit the number of drive wheels such a vehicle may have: one, two, three, four or more. It also may be used with any wheel with a diameter greater than five inches.

LOGIC UNIT

We chose to implement the logic module using microprocessor technology, because of its relative immunity to ambient conditions compared to analog devices, its potential for easy behavior modification in software, and because of the ability to easily interface a wide variety of command input devices (force or displacement sensitive joysticks, sip and puff, head position, capacitive touch plate, et al.) to a digital system. Using an inexpensive microcomputer (the Zilog Z80A), we have been able to implement an interactive wheelchair controller: the programmer can write and immediately test each section of code on the actual target device, because it has a language/operating system (FORTH) imbedded in the device. Presently, this controller is running a Proportional-Integral control routine on three motors simultaneously. The same controller will soon be mounted on a conventional two-wheeled wheelchair for user evaluation purposes, this requiring only minor modifications in the program, and none in the actual circuitry.

CHASSIS AND SUSPENSION

The function of vehicle frame and suspension were integrated in our application through the use of flexible composite plates to tie the drive units together. These plates were designed to provide vertical and longitudinal, but no lateral compliance in two very inexpensive and durable parts. In fact, here too the vehicle can be tailored to the needs or desires of the individual, by shaping these plates as required, and by choosing the materials and dimensions used in fabrication to yield the suspension characteristics desired.

SEATING

The seating system is separate from the powered chassis, in accordance with the guidelines set forth at the Wheelchair III conference. This makes it possible for the same general chassis configuration to be used with a wide variety of seating systems. Since the Alexis vehicle was not intended for a specific end user, the fitting of an orthotic seating system was deemed unnecessary, instead, a Recaro Idealseat was mounted on the chassis to provide an adjustable, orthopedically acceptable seat. This seat was slightly modified by its manufacturer to allow the mounting of the joystick in one of the seat bolsters as styling detail.

POWER STORAGE

Two sealed suspended electrolyte batteries were used, supported in such a way as to allow a wide variety of battery sizes to be accomodated by the vehicle. Ideally, these batteries should tolerate rapid charge cycles, and the vehicle should be equipped with an on-board charger. Combined with an energy monitoring system, such a system would go a long way towards increasing the owner's confidence in their vehicle, thus increasing their freedom of mobility.

CONCLUSION

The division of a mobility system into functional modules provides the opportunity to greatly enhance the relationship between a person and their vehicle by making very specialized machines technically and economically possible. Further, the potentially greater production levels of these modules promises to greatly lower consumer purchase and replacement costs for this parts. Proper design of these elements and their interaction could reduce the skill and equipment required to service vehicles built up from a collection of these functional blocks. This method of component design is a promising avenue for future investigation and development.

THE USE OF MICROPROCESSORS IN POWER WHEELCHAIR CONTROLS

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ABSTRACT - The use of microprocessors (µP) in powered wheelchairs is being discussed and realized increasingly. This paper deals with the question what advantages in technical view and in utility value can be anticipated considering the basic characteristics of human locomotion control as well as the individual demands in adaptation of the wheelchair control systems' peculiarities to different disabilities.

RÉSUMÉ - On parle de plus en plus de l'utilisation des microprocesseurs dans les fauteuils roulants motorisés et ont fait de plus en plus de réalisations à cet égard. Cette communication tente de déterminer quels sont les avantages, du point de vue technique et de la valeur utilitaire, que l'on peut prévoir en tenant compte des caractéristiques de base de la locomotion humaine et des besoins individuels en ce qui a trait à l'adaptation des particularités des systèmes de contrôle des fauteuils roulants à différents types d'invalidités.

The use of microprocessors in power wheelchairs is discussed and realized increasingly. The reason being, besides the actual low-priced availability of these devices, the flexibility of micro-computer design, e.g. changes in function can be performed without considerable changes of application.

To get an idea, where in power wheelchairs these possibilities of more variability can favourably be used, have a look at a simplified man-machine-model which is illustrated by concrete examples of power wheelchair control.

Figure 1 shows the subsystems man-machine resp. disabled person - wheelchair.

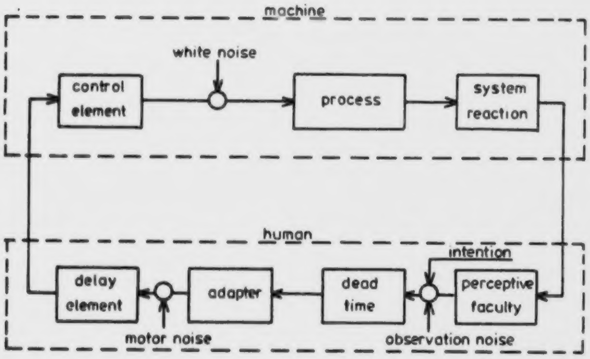

Figure 1

The control behaviour of man is represented in the schematic diagram by the following functions: A dead time section represents the reaction behaviour of man, caused by the excitation time of the involved sensors, the definite transfer time of nerves, and the central nervous processing time. The following adapter describes in general the adaptibility of man by different control problems. The neuro-muscular delay-line defines the motorial behaviour, e.g. it describes the activation of muscles and the movement of the arm-hand control element system. The acting irritations on the perceptional side are defined as 'observation noise'. The acting irritations on the motorial side are defined as 'motor noise'. Observation noise and motor noise can be immediately interpreted as consequence of the limited precision of man, by the sensorial input and the motorial output of information. Therefore, the magnitude of these disturbances is mainly influenced by the specifications of the applied displays and control elements.

The machine resp. electrical wheelchair model is characterized by the following functional module. Man interferes with the control process by a control element, which in wheelchair applications is usually a joystick. The dynamic specifications of wheelchairs are summarized in the functional module. The resulting variables of state, the driving behaviour in first approximation, are observed and interpreted by man and in cooperation with a determined intention of locomotion results, a new travel through the control loop. The designer is able to control the flow diagram from the intention of the wheelchair driver to change his standpoint to the realized wheelchair movement. In detail the interface, the acuating variable, the process under the influence of noise and the variables of state are to be defined and realized.

The control element at the beginning of the flow diagram is usually realized by joystick steering. With the aid of a one-hand-level-system it is determinated as well direction as speed of the wheelchair. If the joystick is point of intersection of both axis of a carthesian coordinate system, change of abscissa leads to change of deviation angle, change of ordinate leads to change of speed. For this transformation a linear transient response was choosen because of the simple way of realisation, for the deviation angle axis as well as for the speed angle axis. (See fig. 2)

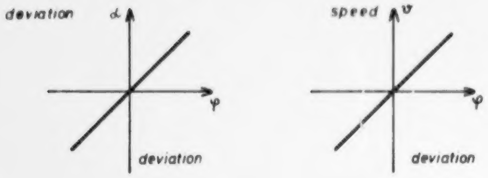

Fig.2

But watching activities of daily life we see that reactions and responses to a variety of stimuli or of acts are not linear at all. In the action 'raising a glass of wine' it is uncommon to perform the movement of the arm during the whole operation with constant velocity; moreover a intuitively builded and unconsciously stored motionmatrix provides a variation of speed depending on the distance wine-glass to mouth (at least at the beginning of the test). The approach to fundamental characteristics of control mechanism in natural movement processes leads to a facilitated psycho-physical adaption and the handling of the joystick is easier to learn. Therefore, the introduction of nonlinear characteristics is desirable. With the aid of microprocessors and the associated memory devices it is possible to realize 'personal control characteristics'. A certain set of characteristics will be defined and stored. The user of the wheelchair can now determine the optimal driving behaviour by his personal choice of deviation angle - and speed characteristics.

Together with disabled persons we have performed drive tests, thereby the following characteristics got most acceptance. (See fig. 3.)

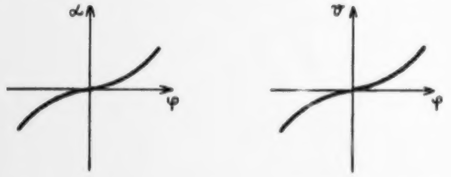

Fig.3

The wish of the power wheelchair user to have available different characteristics according to the speed leads to dynamical characteristics. A variation of the deviation-forces of the control lever (the result is an active control lever) is topic of actual research. The nonlinear characteristics, shown in Figure 3, are already used in our standard wheelchair.

The second part of the technical realisation of the wheelchair system is the controller, it is usually realized by an analog, discrete electronic circuit. The advantage of speed stands opposite the disadvantage of non flexibility; e.g. already simple variation of time constant causes changes in the constructional details of the circuit.

Regarding direct digital controls only poor control algorithms can be implemented, because of the relatively long lasting machine cycles of available 8 Bit Processors. On the other side the inherent precision is of advantage concerning the control behaviour.

Moreover the advantages of microprocessors are:

- a variable control behaviour can be defined and programmed. The use of different controlalgorithms fascilitates learning.
- predifined system conditions can be stored and be compared with actual system parameters. The accquisition of non-permitted or for the occupant dangerous conditions, as changes of position, acceleration or centrifugal system variations, leads, when exceeding a certain security level to a preprogrammed reduction of speed, acceleration or deviation changes.
- external functions like communication aids or functional aids can be controlled by the wheelchair user. This entrances interpersonal exchanges as well as independence.
- The reliability of the whole electronic device is increased by the reduced number of electronic parts and by the possibility to implement sophisticated circuit checks.

The immense possibilities of microprocessor applications harmonize the variety of human behaviour and experience. Efforts to bring these technical advantages to the disabled people is an extraordinary task and a great responsibility of the technique.

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THE HUMAN FACTORS DESIGN OF A POWERED WHEELCHAIR CONTROLLER

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ABSTRACT - This paper describes the hardware/software components of an advanced intelligent control system for power-driven wheelchairs. Many of the characteristics incorporated were determined first by careful survey of powered wheelchair users. The electronics engineering followed the human factors engineering throughout this the project.

RÉSUMÉ - On décrit dans la communication que voici le matériel et le logiciel d'un système de commande intelligent de fauteuil roulant motorisé. Nombres des caractéristiques intégrées ont été d'abord déterminées par une enquête auprès des usagers de fauteuils motorisés. Tout au long de ce projet, la conception électronique a toujours cédé le pas à la conception des facteurs d'adaptation humains.

1. INTRODUCTION

At present all powered wheelchair controllers on the market are of the analog type. They were first introduced more than twenty-five years ago and the present designs are based on pulse-width modulation with BJT output developed in the early sixties. There have been minor improvements since that time, but the basic controller characteristics have remained the same.

Present controllers have a high retail cost exceeding $1200.00. The system presented in this paper is expected to reduce this by one third as well as provide considerably increased flexibility with human engineering.

In order to implement human factors considerations in wheelchair control, the controller should consist of a few basic components. This paper will discuss the human factors considerations and provide technical descriptions of each of these components as listed below:

2.1 Microcontroller (MPU)
2.2 Joystick input
2.3 Velocity Encoder input
2.4 Motor control
2.5 Programming interface
2.6 Accessories

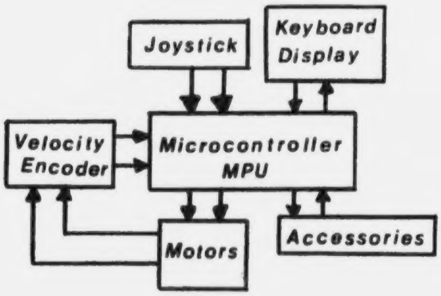

Figure 1.

2. PRESENTATION

2.1 MICROCONTROLLER (MPU)

In order to have maximum flexibility in one controller, a microprocessor-based design is essential. Existing controllers require hardware modifications to adapt the controller to the special needs of some disabled persons. Since all the characteristics of these controllers are built into the hardware, the user or therapist has no selection of functions, or capability to modify parameters over time in the event the patient/client's disability changes with respect to user learning.

An improved controller could be customized with software and provide:

(1) programmability of allowed maximum forward velocity, reverse velocity, and maximum accelerations.
(2) programmed input averaging strategies to compensate for spasticity (resulting in smooth and safe motion).
(3) programming for particular user inputs (joystick, chin switch, puff and sip, and newer controls that may not have been developed as yet).
(4) storage of power output parameters allowing the user to drive into a crowded area and then have the controller automatically back him out.
(5) the option to program in new joystick input schemes to get such features as acceleration control, logarithmic control, modified axis control, or whatever other type of control is optimal for the user.

The MPU consists of a single chip microcontroller (INTEL 8048/8049), a port expander (INTEL 8243), and 5 volt EEPROM external memory (XICOR X2816 and address latch 74LS373).

The 8048 was chosen because it was designed to be an efficient controller and is a very low-cost device. The EPROM version of the 8048 (the 8748) simplifies prototyping and can be used in low-volume custom built models. The 8048 is an 8-bit CPU with internal clock, 8-bit timer, 1k of EPROM, 64 bytes of RAM and 27 I/O lines. (The 8049 has 2k EPROM, 128 bytes of RAM and is pin compatible to the 8048). The 8048 operates on a 6 MHz crystal with a 2.5 microsecond instruction cycle.

The XICOR X2816 5 volt only EEPROM is essential for nonvolatile storage of the control parameters which are used to customize the chair for the individual user. Typically the ten millisecond write time for the X2816 prohibits its use for temporary data storage, but with a thirty millisecond sampling period a portion of the memory can be used for back-up parameter storage.

2.2 JOYSTICK INPUT

This controller uses a standard wheelchair joystick so that this man-machine interface is left in tact. The processor "looks" at the joystick position every 30 milliseconds which is a quite adequate sampling time in light of the fact that the response time of an able-bodied person is on the order of 200 milliseconds when performing complex tracking tasks as is done in controlling a wheelchair with a joystick.

There are a number of things which the processor can do to make joystick control easier. Standard steering allows 90 degrees of latitude sweep before one wheel stops and begins to reverse. An improved scheme could be programmed into the controller to broaden this range to 120 degrees. Other possibilities include variation of the dead band or non-linear/time varying mappings of joystick position to wheel speed. Another strategy might implement proportional control of acceleration rather than velocity. This would allow cruise control as well as a simplified control strategy for some disabled persons.

Instead of using linearly scaled joystick control a logarithmic scale might be used to regulate velocity, providing fine resolution control at low speeds .

ANALOG TO DIGITAL (A/D) CONVERSION

This design uses an A/D input technique similar to the way the Apple II "reads" its analog game paddles. This method minimizes computing load on the 8048 by having the A/D conversion done externally.

A 558 quad R-C timer and an INTEL 8253 interval timer perform the A/D conversion for the two joystick potentiometers simultaneously. This component communicates through a data bus using a 1 Mhz clock signal provided by the 8048. A resolution of 100 bits from full speed reverse to full speed forward is achieved this way and the current joystick position is determined in 300 microseconds.

2.3 VELOCITY ENCODER INPUT

From control theory it is known that knowledge of two states (velocity and position) is required to maintain a controllable system. In a normal (open loop) controller the user must monitor these states and provide feedback to the system through the joystick. However, if velocity compensation were provided by the controller, the user would have a simpler control task.

In the standard "open-loop" controller direction vector, speed, and acceleration are all functions of: user input, surface incline, and left-right motor calibration. But with the improved microprocessor based controller these parameters are a function of user input only, and even this input can be monitored and limited to "reasonable" accelerations, etc.

Implementation of a proportional velocity control would provide the following:

(1) non-veer driving on inclined surfaces.
(2) direct joystick position velocity control allowing the user to maintain a certain unique speed no matter what the terrain, uphill or downhill.
(3) joystick rest position being interpreted as zero velocity so that on hills there is no rollback or rollforward (a warning signal could then remind the user to lock on the manual brakes to avoid battery drain).
(4) no need to calibrate left and right motors for even power control.

ENCODER INTERFACING

Many velocity sensors do not provide the resolution or accuracy needed for real time control of a wheelchair. In order to implement the above discussed sophisticated control strategies a high resolution optical encoder (the PMI M-15-500 - 500 counts per revolution) was mounted on the motor shaft to provide a control resolution of 1/10 of a mile-an-hour.

The M-15 operates from a 5-volt supply and has dual squarewave outputs in quadrature (for detecting direction). This component communicates through the data bus with an 8253 counter such that the A/D conversion is done externally and the processor does not waste time handling this conversion.

2.4 MOTOR CONTROL

A new design in power processing circuitry has been implemented for human factors considerations. The majority of present controllers have an annoying 400 hertz hum while in operation, and a circuit design with relays that cause a considerable amount of chatter when maneuvering in confined areas or traveling down inclined surfaces. This noise is eliminated in the new controller which operates at a silent 20 KHz and uses solid state forward/reverse switches instead of the chattering relays.

The 8048 provides a 1 MHz clock signal for an 8253 interval timer which controls the pulse-width modulation of the 20 KHz drive circuit. This timer communicates with the MPU through the data bus and provides a duty cycle resolution of 2%. The MPU is protected from the power circuitry by optical isolation.

The recent introduction of high current MOSFET's (Motorola's TMOS series) provides the most promising option for power processing in powered wheelchairs. These MOSFET's (MTE100N06 - 100 amp) have been incorporated in a chopper circuit together with SCR's which are used as silent forward/reverse relays. Inductive energy stored in the motors is returned to the battery on each cycle extending possible time between charging and increasing battery life. Controlled regenerative braking will be incorporated into the final version of the controller.

2.5 PROGAMMING INTERFACE

This new controller is designed such that it may be easily programmed by a user or therapist. The programming is done through an RS-232 interface which may be connected to any keyboard and display which has a standard RS-232 interface. This will allow easy programming by anyone who as a standard computer terminal, microcomputer, etc.

2.6 ACCESSORIES

Because most of the control functions are performed external to the 8048, this controller has a lot of "free time" and is capable of doing many more things. It could control on-chair devices such as a leg-bag evacuator, recliner, turning lights, etc. It could monitor user physiological functions and control a power-assisted orthosis. The controller could function as a portable communication aid or environmental control. The microprocessor could monitor battery voltage, perform self-diagnostics (with modular design), give musical warnings or problem signals, display velocity, miles traveled, miles since charge, etc. With this type of software-based design, the possiblities for expansion are enormous.

3. CONCLUSION

The intelligent control system described in this paper provides a sophisticated control for powered wheelchairs of virtually all makes and models not only for today, but for tomorrow's wheelchairs as well. The system is comprehensive enough to be expandable and modular enough to be versatile to the point that almost any human factor can be accommodated. Being of digital design and with software engineering establishing virtually all operating characteristics, this system provides a means of making one size fit all. In addition the costs are surprisingly realistic. The optical encoders are the single most expensive component and the electronics continue to become less expensive each month. It is not overly optimistic to conclude that this design can be implemented for a user cost of up to one third less than the present control systems on the market and provide a more reliable system with the user's needs designed into the system.

The Intel 8049 with double the memory and a clock rate of 11 MHz could provide for expansion to handle special cases or new vehicles which may utilize four wheel drive and perhaps four wheel steering.

Most importantly, the user for the first time may have new options and features which will improve the quality of his life as well as provide him with safer and more efficient transportation.

ECR - ÉLÉVATEUR DE CHAISES ROULANTES

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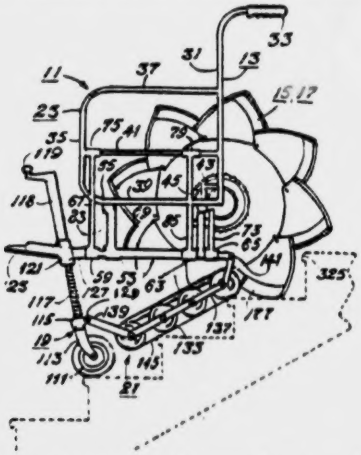
RÉSUMÉ - Système amovible d'élévation de chaises roulantes, actionné soit par un petit moteur électrique, soit manuellement, au moyen d'une manivelle, lequel peut être utilisé dans des escaliers communs, étant appliqué sur les marches, sans aucun type de fixation à n'importe quel point de l'escalier.

ABSTRACT - Detachable system for lifting wheelchairs, operated either by a small electric motor or manually with a crank, which can be used in ordinary stairways; it is applied to the steps, without being attached in any way, at any point along the stairway.

Les barrieres architectoniques constituent le plus grave problème pour les handicapés moteurs, la plus commune étant les escaliers. Ceux-ci sont une forme pratique pour que les non-handicapés franchissent des dénivellarions, mais constituent un obstacle pour ceux que, ne pouvant pas utilizer leurs membres inférieurs, sont obligés de se déplacer en chaises roulants.

Récemment il y a eu deux tendances pour essayer de résoudre ou amoindrir ce grave problème. D'un côté, concevoir des constructions où les barrières soient éliminées et où les usagers, handicapés ou pas, puissent circuler librement. Pourtant, cette tendance est encore très récente, et de l'autre côté, la plupart des bâtiments a de grands escaliers, ceux-ci étant plus ou moins longs selon la magnificence des bâtiments. Les villas ont d'habitude plus d'un étage, raison pour laquelle elles n'ont pas d'ascenseurs.

C'est là qu'on trouve l'autre tendance: les inventeurs commencent à construire des appareils plus ou moins sophistiqués que permettent le déplacement de chaises roulantes sur les marches.

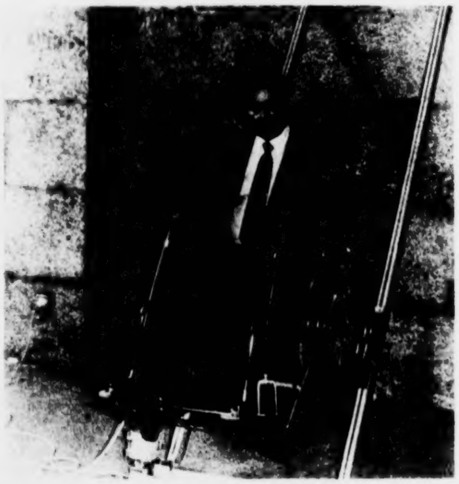


Il y a eu beaucoup d'inventions, mais dans la plupart elles n'ont été que de bons idéaux, mais tout à fait irréalisables.

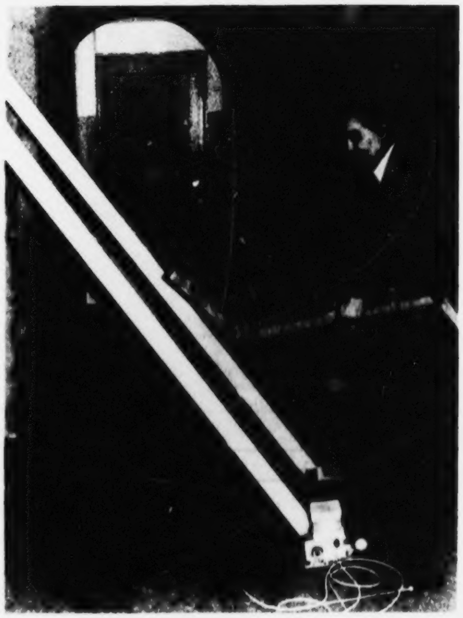
Pourtant, d'autres sont bien éfficaces, particulièrement les plate-formes élecatoires qui existent dans les habitations. Il s'agit d'installations fixes qui permettent le transport des handicapés ou gens âgés dans leurs chaises roulantes.

Mais, ces installations étant fixes, elles ne peuvent être utilisées que là où elles ont été montées. Il faut donc créer des mécanismes que permettent de franchir toute rampe d'escalier.

Il y a quelques systèmes, chacun ayant ses avantages et ses inconvénients. De tous ceux que je connais, l'ECR me semble le plus pratique, économique et portable. L'ECR est un système qui consiste à deux rails, un moteur éléctrique et une plate-forme d'élévation. Il existe en deux versions: 2 rails semi-fixes appuyés sur les marches d'un escalier à largeur suffisante, pouvant toutefois être appliqués à d'autres endroits, puisqu'il n'y a pas de liaison fixe entre les rails et l'escalier.



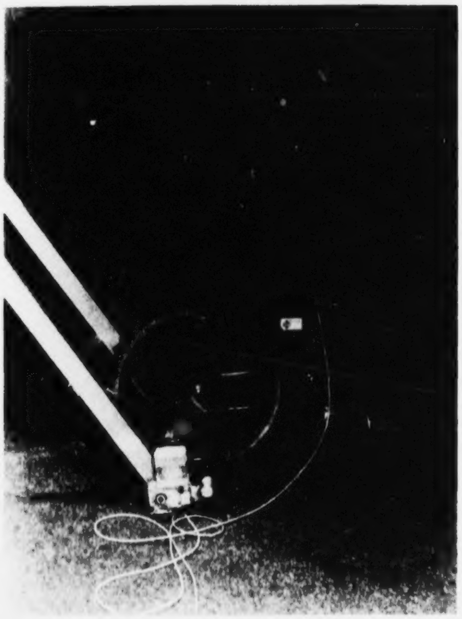
Un petit moteur éléctrique monophasé de condensateur élève la plate-forme jusqu'à la hauteur désirée, pouvant l'handicapé lui même mettre en marche le système. Dans le cas d'une panne de courant, le système peut être mis en marche à l'aide d'une manivelle actionnée par une autre personne, ce qu'on peut faire avec un peu d'effort dû à la démultiplication des engrenages.



Dans une autre version, entièrement portable, le système est constitué par des corps interpénétrables pour permettre la "construction" d'une structure capable de franchir une rampe d'escalier, toutes les pièces pouvant être transportées dans le coffre à bagages. Ça c'est un système versatile que peut aussi être mis en marche manuellement, le quel l'handicapé qui se déplace en voiture pourra toujours transporter pour l'aider à franchir les marches des bâtiments où il a besoin de se rendre.

L'handicapé lui même peut relier les pièces et mettre en marche le moteur, mais on recommende l'aide d'une autre personne.

Dans le cas des villas ou d'habitations où il y a d'autres locataires, le système peut être installé définitivement, permettant la circulation entre les rails, ou être rangé contre le mûr, ou encore enlever la plate-forme élévatoire, puisqu'elle est démontable. Pour plus d'une rampe d'escalier, il faudra avoir plus d'un système de rails, mais l'utilisation de plus de 2 ensembles est peu pratique.



PSYCHOSOCIAL CONSIDERATIONS IN WHEELCHAIR DESIGN - CONSUMERS' EVALUATION OF CURRENT AND PROPOSED ASSISTIVE DEVICES

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ABSTRACT - Four hundred wheelchair users were surveyed concerning their subjective responses to their current wheelchair, as well as changes they would make in the design to enhance performance and improve their quality of life. Implications for future consumer involvement are discussed.

RÉSUMÉ - Quatre cents usagers de fauteuils roulants ont fait l'objet d'une étude portant sur leurs réactions à leur fauteuil roulant actuel et sur les changements qu'ils apporteraient à leurs fauteuils pour en améliorer le fonctionnement et améliorer leur propre qualité de vie. Les conséquences pour leur future participation en qualité de consommateurs sont abordées.

INTRODUCTION

Although progress has been made concerning the use of new technology in the design of prosthetic devices such as wheelchairs, little attention has been given to the input consumers can make in each step of the design process. Excellent position papers expounding the necessity of consumer involvement abound (e.g. Lauer,1981, Pfrommer,1981), but few well-controlled studies have made an impact on either the scientific or popular press. As steps are made describing the objective criteria necessary for standards in wheelchair design, so should steps be made detailing the subjective analysis by current users. In addition, the psychosocial impact of each prosthetic device should be addressed, and assessed within the context of each consumer's lifestyle, physical environment, interactions with family,friends, and coworkers, as well as his/her concept of him/herself along variables such as independence, attractiveness, and vulnerability.

GOALS OF THE STUDY

The goals of this study were multifaceted.

1. To survey a large cross-section of the physically disabled community concerning their subjective satisfaction with their current wheelchair,
2. To document potential positive psychosocial changes associated with the reduction of their prosthetic needs,
3. To document what changes consumers would like to see made to their wheelchair, given the cost of each positive change;
4. To disseminate the report of the consumer evaluation through scientific and popular channels in order to aid in the selection and design of future prosthetic aids, and
5. To develop an ongoing consumer roundtable concerning itself with the development and evaluation of prosthetic devices. This group consists of consumers,engineers,psychologists, social workers,occupational & physical therapists, and prosthetics personnel. This advisory group serves as both a sounding board for new prosthetic concepts as well as a mechanism for consumers to influence future prosthetic design proposals.

METHOD

Four hundred questionnaires evaluating sixty-five different aspects of wheelchair design were disseminated though The Paralyzed Veterans of America chapter newsletter (Table 1). In addition, twenty-seven questions concerning the psychosocial impact of prosthetic devices were included (Table 2). The results of this questionnaire were tabulated and cost-estimates were done on the items scoring poorest on the consumer evaluation. The consumers were then given a second questionnaire listing a hypothetical wheelchair with given specifications,along with a cost-estimate of eliminating the various most frequently described problem areas. The subjects were then told that they had a hypothetical amount of money that they could either use to modify their fictitious wheelchair or use in any other manner that they wished. In this design, we attempted to simulate a more real situation that would face a consumer. Results of both questionnaires were then analyzed to determine if psychosocial variables (e.g. length of time since injury, housing status, lifestyle, income, etc.) had any effect on the responses given by the consumers concerning variables related to the evaluation of their needs via their evaluation of the wheelchairs.

TABLE 1
COMPOSITE LIST OF MANUAL AND ELECTRIC WHEELCHAIR COMPONENTS SUBJECTIVELY RATED BY CONSUMERS

Height
Weight
Length
Width
Reliability
Durability
Safety
Seat comfort
Stability
Ease of transfers
Ride quality
Underneath clearance
Frame strength
Hill holding
Adjustable armrests
Battery life
Battery charge time
Battery recharge time
Access to batteries
Speed/velocity
Control stick
Noise
Curb climbing
Acceleration
Rain operation
Trunk supports
Reverse indicator
Alarm system
Mirrors, lights, horns
Charge indicator
Tool kit
Traction
Purchase price
Ease of cleaning
Handrim material
Handrim shape
Handrim diameter
Cost of servicing chair
Availability of parts
Collapsed size
Storage space
Style/esthetics
Turning radius
Wheel/spoke style
Self-servicing
Sealed bearings
Variable speed(manual)
Standing frame attachment
Lever operated(manual)
Downhill turning
Control smoothness
Placement of controls
Precision of controls
Low speed maneuvering
Speed regulation on hills
"Jumpiness" in braking
Free wheel capability
Lapboard
Seat recline/elevation
Chair mounted charger
Variable speed (manual)
Fail safe parking brakes
Ability to go into shower
Frequency of repair this year
Number of days wheelchair unusable this year

TABLE 2
POTENTIAL PSYCHOSOCIAL BENIFITS VIA PROSTHETICS
(adapted from Preston, 1981)

If you were able to design, build, and use the "perfect" wheelchair, which of the following statements would be true in describing you and your relationships?

T F family enjoys more social life
T F more independence
T F increase in social activities
T F more contact with peers
T F allowed more normal function
T F increases activities at school
T F sitting habits changed
T F like your appearance more
T F family living habits more ordered
T F less time required of others
T F increased traveling
T F less trips to medical facilities needed
T F less need for help in management
T F increased work contact
T F eating habits aided
T F toileting habits aided
T F sleeping habits aided
T F need less restructuring of surroundings
T F increased leisure time
T F feeling of less conspicuousness
T F increased self esteem
T F decreased feeling of vulnerability
T F decreased perceived stress in life
T F increased body tone
T F decreased spasms
T F decreased pain
T F decreased marital/relationship problems

RESULTS AND DISCUSSION

Comments from the advisory group and early results from the questionnaires indicate a great deal of sophistication on the part of consumers in describing, discriminating, and analyzing various aspects of wheelchair construction, as well as synthesizing these subjective reports with correlated psychosocial phenomena. Results of both surveys will be discussed, as well as data and impressions gathered at the consumers roundtable meetings.

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A WHEELCHAIR BUMPER IN SPORTS FOR THE DISABLED

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ABSTRACT - This paper describes a newly developed wheelchair bumper and introduces a team game called "Motor Soccer", for which the bumper was originally designed. The bumper protects the feet in a collision, both when playing the game of motor soccer and in normal daily activities. Motor soccer enables those in electric wheelchairs to participate in a competitive team sport.

RESUME - Ce texte décrit un pare-chocs nouvellement développé pour les chaises roulantes, et introduit le jeu "Motor Soccer", pour lequel le pare-chocs a été originellement construit afin de protéger les pieds en cas de collision. Le jeu "Motor Soccer" permet aux personnes en chaise roulante électrique de participer à un sport d'équipe compétitif.

INTRODUCTION

Recreational games are very important in the rehabilitation of handicapped persons. Games and socialization opportunities for persons in electric wheelchairs are a special challenge, because of the severity of the disability. These recreational needs can be met through participation in team sports. However, until recently there has been no team sport for persons requiring the use of electric wheelchairs. This paper describes a wheelchair bumper which was designed for a team game called "Motor Soccer". The game and other uses for the bumper are discussed in the paper.

THE WHEELCHAIR BUMPER

In designing the bumper, the following criteria were set down:

1. It should fit virtually any wheelchair.
2. The height and width should be such that the users are protected in the event of a collision with another bumper.
3. The bumper should be shatter proof (an important consideration because of the very real danger of collision during wheelchair sports).
4. The connection between the bumper and the wheelchair should be sufficiently rigid so that it would not be torn away in a collision.

A bumper which meets all of the above criteria can be seen in figure 1. It is vacuum formed from 3/16" high density polyethylene. Its shape is made so that it will envelop the feet of the user as much as possible, without restricting transfers in and out of the wheelchair. To connect the bumper to the wheelchair, it is simply necessary to remove the small rubber tips from the foot rests and slide on the bumper. It is fixed to the wheelchair by the same metal screws that are used to hold the rubber tips.

The bumper was designed to withstand a 5 m/s impact when attached to a 150 kg. electric wheelchair, ridden by an 80 kg. user. Tests showed that the bumper was well able to withstand such an impact. However, some of the wheelchairs tested suffered structural damage as a result of the impacts. Thus, users must be advised against having a false sense of security when using the bumper. Injury could still occur if the wheelchair itself collapsed in an impact.

MOTOR SOCCER

Motor Soccer, developed simultaneously by Leisure Services at the Royal Ottawa Regional Rehabilitation Centre and the British Columbia division of the Canadian Wheelchair Sports Association, is shown in figure 1. The object of the game, using electric wheelchairs only, is to propel the ball over the opponent's goal line. Most rules comply with those of field soccer.

The ball is a "Gymnastik" ball, either 60 cm in diameter (used in Ottawa) or 90 cm in diameter (used in Vancouver). A minimum diameter of 60 cm is necessary to prevent the ball from becoming lodged under the wheelchair, causing it to flip backwards. The Gymnastik ball is especially recommended because of its durable skin and light weight.

In Motor Soccer, each team is allowed a maximum of four players on the court at one time. Both males and females compete together and there are no age restrictions. The playing area is a regulation basketball court and the goal is 3 metres wide. Each game is made up of two 30 minute halves, with a 10 minute break in between. The play begins in each half, and after each goal, in the same manner as field soccer. At no time is any player allowed to use his (or her) arms or hands to move the ball.

If this infraction occurs, possession of the ball is awarded to the other team . When the ball becomes lodged between two opponents so that it is immovable for at least three seconds, it is considered a dead ball and the play is stopped. Play is resumed with a face-off between these two players. If any player causes the ball to go out of bounds, the opposing team is awarded possession of the ball at the point where it left the playing area.

Although incidental contact between wheelchairs is allowed (e.g., while two players move for the ball) there is a two minute penalty for any player who charges another - either accidentally or intentionally - with his (or her) wheelchair. Because of the potential for contact between wheelchairs and because of the need to have a firm smooth surface to push the ball, the wheelchair bumper has become a standard item of equipment for Motor Soccer in Ottawa.

Motor Soccer, while still in its infancy, has been accepted with enthusiasm by disabled individuals who play it on a regular basis. The game is providing a unique opportunity for persons in electric wheelchairs to participate in a team sport.

MODIFICATIONS TO THE BUMPER

In a year and a half of continuous use, only minor modifications and changes were required for specific users. One example was a player who had a very high foot rest. The height from the floor made it possible for her to go over other wheelchair bumpers. Furthermore the ball, in spite of its large diameter, would go under her bumper, lifting the front wheels off the floor (a potentially hazardous situation). To solve this problem, special blocks were made to lower the bumper to an acceptable level. Although this uncovered the feet somewhat, they still remained sufficiently protected because of their height and the distance between the front of the bumper and the toes. Modifications were made for other users as they became necessary.

OTHER USES FOR THE BUMPER

The wheelchair bumper has found other uses outside of sports. Users of electric wheelchairs, whose control is limited because of the extent of their disability, use it to protect themselves in the event of an accidental collision. Other wheelchair users find it protects walls and furniture in their homes from being damaged by the metal footrests.

CONCLUSION

The bumper and the game of Motor Soccer, for which it was originally designed, have been very beneficial to, and popular with, a significant segment of the disabled population.

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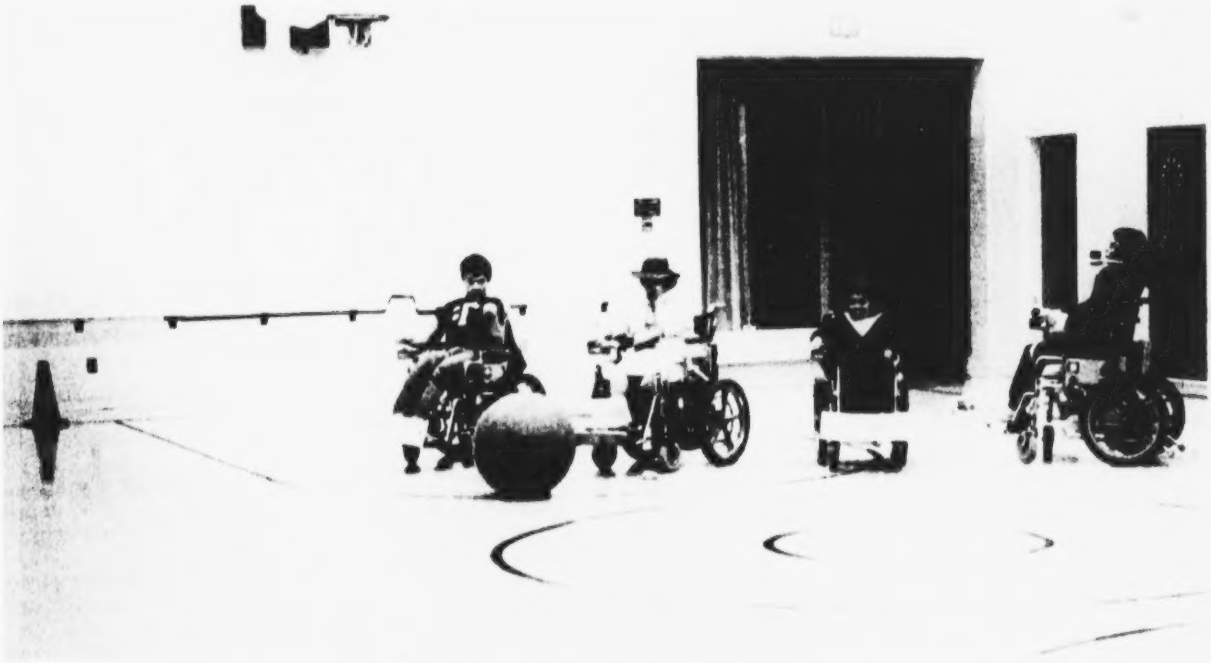

Figure 1. A game of Motor Soccer.

INCREASED TURNING RESISTANCE DUE TO A GROOVED WHEELCHAIR CASTER WHEEL

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ABSTRACT - The increased turning resistance due to a grooved caster wheel is presented. The results include the methodology and the results of experiments developed to measure the sliding friction turning moment of the wheelchair caster and the additional force exerted by the wheelchair user necessary to turn the wheelchair equipped with grooved caster wheels.

RÉSUMÉ - La résistance de rotation augmentée due à la roulette cannelée est présentée. Les résultats comprennent la méthodologie et les résultats des expériences développées à fin de mesurer la friction de glissement moment de rotation de la roulette du fauteuil roulant et la force additionnelle déployée par l'usager du fauteuil roulant nécessaire pour faire rouler le fauteuil roulant équipé de roulettes cannelées.

INTRODUCTION

Stout [1] noted that at low speeds, maneuverability is hindered by the caster's frictional resistance to turning about the caster axis. In many instances the wheels are not rotating when a turn is attempted. Stout measured the turning friction by setting the caster wheels straight ahead and measuring the force applied at the front of the frame necessary to laterally move the frame 1/2 in. Tests similar to Stout's were conducted by Kauzlarich [2] with respect to electric powered wheelchairs.

In an attempt to eliminate front caster shimmy, studies by Kauzlarich [3] indicate that a grooved caster wheel significantly increases the speed at which caster shimmy is self excited. Hence, by equipping the wheelchairs with grooved caster wheels shimmy can virtually be eliminated because the speed necessary to initiate shimmy is much higher than the normal operating speed of the wheelchair. This will effectively increase stability and decrease power consumption. The questions that must be answered are what penalties must be paid for these benefits. The major penalty is the probable increased turning resistance due to the groove. This paper attempts to answer this question.

MODEL

Two caster wheels were used in the study. Both 7-3/4 in . diameter tires were made of polyurethane but with different geometry cross sections, figure 1. Two modes of tire turning were investigated. The first test measured the sliding friction turning moment necessary to turn a non rotating wheel on tile and carpet surfaces. The second experiment measured the force required by the user to turn an experimental wheelchair frame as the caster wheel trail was varied and as the caster load varied.

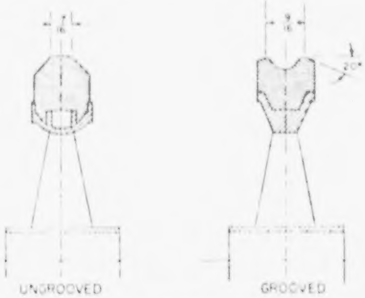

FIGURE 1 Polyurethane caster wheel cross-sections

1. Sliding Friction Turning Moment

To determine the sliding friction turning moment, the caster wheel was mounted in a drill press using an experimental fork. The caster trail in these tests was set to zero. A platform scale was placed on the drill press table and the different materials (tile and short pile carpet) were placed between the the scale and the wheel, figure 2. The

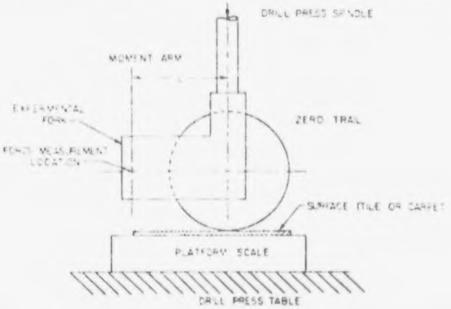

FIGURE 2 Measuring caster wheel turning resistance with a drill press

thrust mechanism on the drill press spindle was used to apply constant normal loads to the wheel and the platform scale indicated the magnitude of the caster load. A force to turn the wheel was applied to the experimental fork level to the wheel axis and perpendicular to the spindle axis of the drill press. A spring scale was used to measure the magnitude of this force.

The results of the test are given in figures 3 and 4. Figure 3 gives the sliding friction turning moment versus normal caster load for three types of wheels on vinyl tile and figure 4 gives information on short pile carpet. The sliding friction turning moments for carpet are approximately double the tile turning moments partially because the carpet tended to build up in front of the caster wheel. A linear regression analysis was performed. The grooved caster required 30 percent more torque than the standard Everest and Jennings gray rubber wheel and 10 percent more torque than the ungrooved wheel made of the same material.

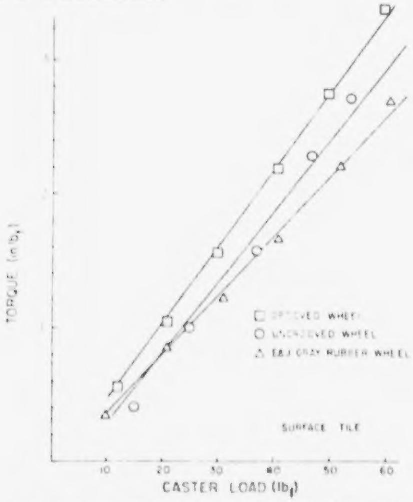

FIGURE 3 The sliding friction turning moment versus normal caster load on tile

2. Force Required to Turn a Wheelchair

To gain an insight into the actual performance of the grooved wheel a test was performed where the wheelchair was constrained to pivot about the right rear wheel. A horizontal force perpendicular to the axle was applied to the left rear axle outboard to the wheel, figure 5. The front two casters were set straight ahead and the force necessary to initiate turning as well as to continue turning was measured. In this test the right rear wheel is constrained so that it only twists and does not roll. The sliding turning moment for the pivoting rear wheel is given in figure 6.

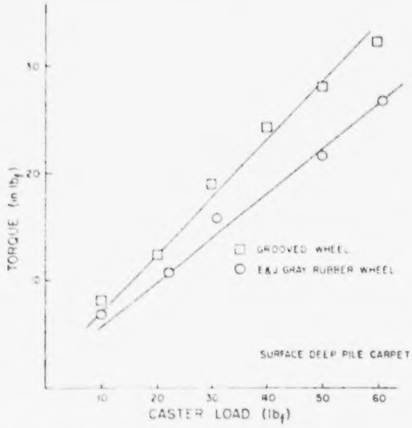

FIGURE 4 The sliding friction turning moment versus normal caster load on carpet

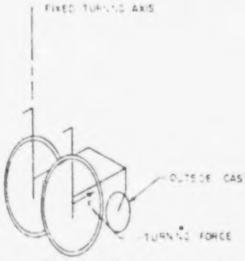

FIGURE 5 Measuring the turning force on an experimental wheelchair

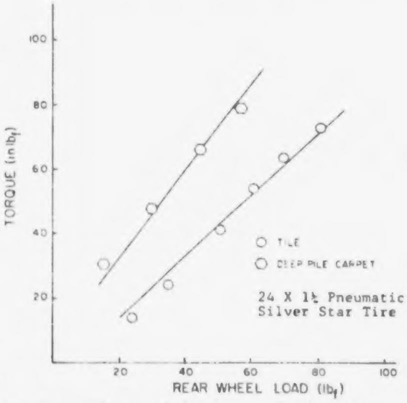

FIGURE 6 The sliding friction turning moment for the rear wheel

RESULTS

The force to initiate turning (10 degrees maximum) is given in figure 7. If a corresponding turning moment of the caster is calculated, it is found that this turning moment is about 50 percent of the value obtained from the non-rotating sliding turning test using the drill press. The grooved wheels require about 10 percent extra effort over the ungrooved wheels. Although the magnitudes of the torques are different, the drill press test gave the same relative difference (10%) in performance. Figure 8 illustrates the force necessary to continue turning the chair. The length of trail roughly correlates to the effort needed to turn the wheelchair, i.e. doubling the trail length will decrease the effort by a factor of two.

An additional factor to note is the initial turning force is not the maximum force needed to continue the turn. The force peaks when the inside caster begins to turn through a larger change in angle than the outside caster as the wheelchair continues to turn. For the geometry of the experimental chair, the relationship between the two turning angles measured relative to the wheelchair frame is given in figure 9. At about 30 degrees turning for the outside wheel, the force is maximum as shown in figure 8.

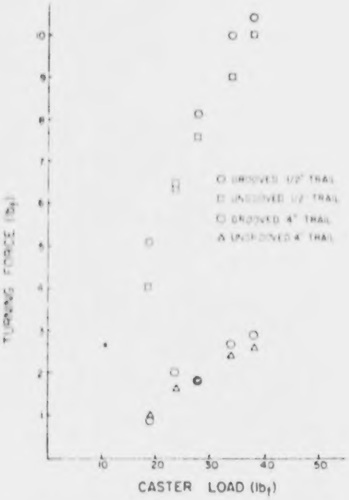

FIGURE 7 The force to initiate turning versus caster load and trail length

CONCLUSION

The grooved caster wheels require approximately 10 percent extra effort when attempting to turn the wheelchair on a rigid surface. A simplified test using a drill press, platform scale and spring scale will give relative information about the turning resistance of different caster wheel geometries.

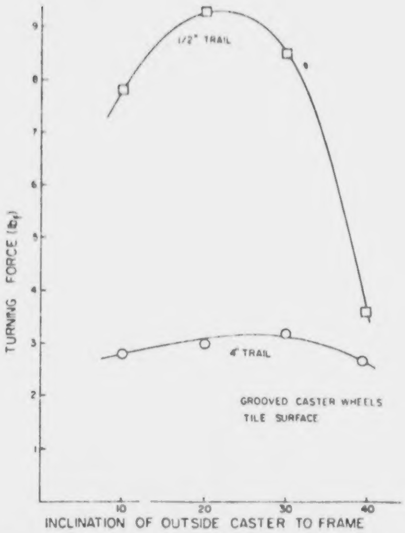

FIGURE 8 The force required to continue turning the wheelchair

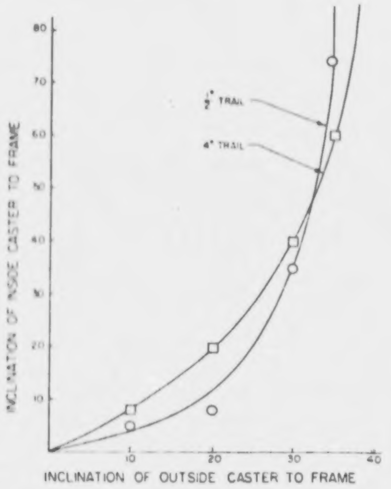

FIGURE 9 The relationship between the two turning caster wheel angles

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OCCUPANT RESTRAINT FOR VANS

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ABSTRACT - The quadriplegic driver who transfers to a van seat requires a seat belt system that not only limits injury in a collision but also gives body support during routine turning and braking. The system described here meets these criteria and is also easy to use.

RÉSUMÉ - L'automobiliste quadriplégique qui prend place dans une fourgonnette a besoin d'une ceinture de sécurité qui, tout en limitant les blessures en cas de collision, retient le torse au cours des virages et des freinages de routine. Le système décrit ici répond à ces exigences et est facile d'emploi.

INTRODUCTION

The quadriplegic who can drive a motor vehicle must often use a van rather than a car for ease of transfer and because, in a van the wheelchair need not be stowed after transfer. In a suitably equipped van the driver's seat moves rearward approximately 460mm (18in.) to facilitate the transfer and then moves forward to the driving position.

When driving, the normal movement of the vehicle causes the body to lean forward during braking and sideways during turns. The weak trunk musculature typical of the quadriplegic means that extra support is required to keep the driver properly positioned behind the wheel. This support is supplied in many ways. The use of wrap-around seats with arm-rests is one method but such seats often interfere with transfers. Another alternative is a well adjusted seat belt with shoulder harness. With limited manual dexterity such harnesses are difficult or impossible to fasten or adjust and they are often attached to the seat or other non-structural part of the van so they are of no value as a driver restraint in a collision.

The system presented here is a seat belt-harness that requires little effort or time for the driver to use and is anchored to the body of the van. It also supplies a constant pressure to keep the driver comfortably supported behind the wheel.

DESIGN

This seat belt system makes use of as much existing van hardware as possible (see fig. 1). Because the seat is mobilized to move rearward for transfer, the standard attachment of the right-hand buckle and the left-hand inertia reels must be altered. These attachments are moved downward from their original locations and secured to the van floor (see fig. 2). The exact location will depend upon the individual van type. The buckle should be positioned as far rearward as possible without interfering with the driver's feet during transfer. Care must be taken to use appropriate nuts, bolts, washers and backup plates while avoiding damage to underbody equipment such as fuel and brake lines or wiring.

The original lap belt segment is modified by the addition of a loop with a plastic stiffener to create an easily manipulated handle. The shoulder segment also has a central loop added but with a plastic hook incorporated which will hook onto the steering wheel. The buckle end of the shoulder strap must be cut and a length adjustment device added to permit positioning of the shoulder strap loop in a mid-chest location.

NEW EQUIPMENT

New equipment required consists of an additional reel, buckle set and webbing. The buckle is floor mounted as illustrated while the reel is ceiling mounted. The reel mounting can be accomplished in many ways. It can be attached directly to the roof in a manner similar to the floor mounting but with due consideration to the cosmetic finish of the van. Alternatively a bar can be secured across the van, as high as possible, and the reel secured to the bar. Suitable material for the bar would be 40x40x2.5mm($1\frac{1}{2}$x$1\frac{1}{2}$x.100in.) hollow structural steel but local regulations and specific design characteristics should be considered. The added webbing passes through the loop on the stock shoulder belt.

The inertia reels must be modified to be used in this system. The modifications required will depend upon the style of reels available. The end result must be reels with elevated spring tension to give body support and inertia locks to prevent rapid movement. The reels must not be static locking.

All the standard quick release buckles are retained so that the system can be released in an emergency or can be used in a conventional way by drivers using the left van door.

OPERATION

The use of this restraint system is described below starting with the driver seated in the driving position. The driver first lifts the lap belt and hooks it over the chest hook. The system is then moved forward and is hooked to the steering wheel. The seat is moved back and transfer is made to the wheelchair. When transferring to the driving position the reverse procedure is used.

CONCLUSION

The seat belt system described here is designed to give the quadriplegic driver functional body support and collision restraint. It is easy and quick to use even with limited dexterity.

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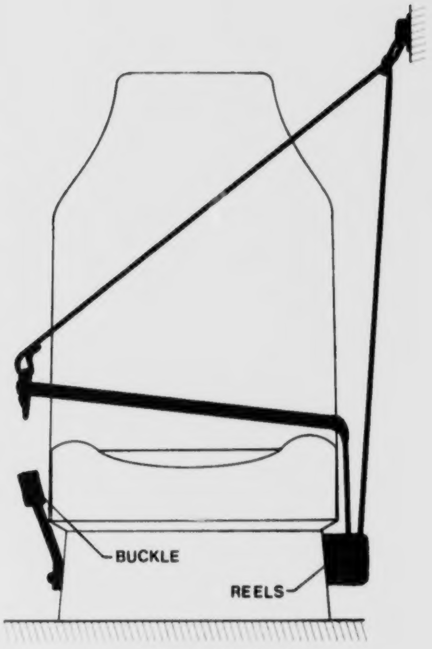
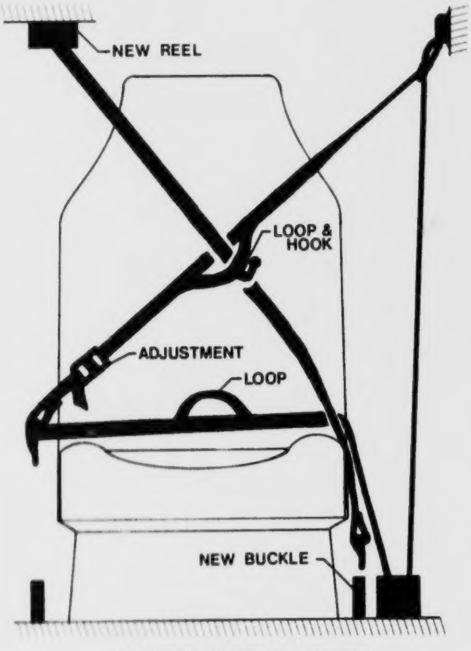


STOCK ASSEMBLY

Figure 1



MODIFIED RESTRAINT SYSTEM

Figure 2

WHEELCHAIR ICE HOCKEY

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ABSTRACT - Two severely handicapped boys are able to move above unassisted on an ice surface in their electrically powered wheelchairs by the application of a traction device to the wheels of their chairs. As well, a simple rotating mechanism was designed to fit onto their chairs allowing the boys to shoot and pass a puck independently. Although the devices were designed specifically for two arthrogypotic boys, the design concept is applicable to handicapped people in general.

INTRODUCTION AND SCOPE

Arthrogyposis is a hereditary disease confining the subject to a wheelchair. Varying degrees of the handicap are possible, ranging from a form of paraplegia to quadriplegia. Two arthrogypotic brothers, ages 5 and 9, provided the impetus to design a mechanism that would allow them to play ice hockey. The five year old boy had no strength in his lower body, arms or hands, although good strength was found at his waist and shoulders. The elder brother had the advantage of partial movement of his arms and hands. The severity of the disease required the boys to be in their electrically powered wheelchairs. The design requirement was twofold. First, a method of providing traction for the wheels on ice was needed, and secondly, a mechanism was necessary to allow a hockey stick to be manipulated.

TRACTION DEVICE

A search of the current market indicated that no special wheels or wheel coverings for wheelchair traction on ice were available. The two boys had different types of wheelchairs requiring different mounting approaches of the traction device. The younger brother had a Beck chair with hard rubber wheels, while his brother had an Everest & Jennings model with pneumatic tires. The principle use for traction on each chair was the same, just a different method of attachment was used. Traction was obtained by imbedding steel studs into low modulus rubber. The rubber was attached to a metal frame, which in turn covered the perimeter of the wheel. For the Everest & Jennings chair, the metal frame consisted of a circular ring. To insert the traction device, the tire was deflated slightly, the ring slipped onto the wheel and then the tire inflated again. Radial pressure from the tire keeps the traction device from coming off. A slotted ring frame with an adjustable clamp was made for the Beck chair for mounting the traction device. Both devices are shown in Photo 1.

HOCKEY STICK MECHANISM

In an effort to make as much use of the youngsters' own abilities, a simple one degree of freedom rotating mechanism was built. The older subject manipulated the stick with his arm, whereas his younger brother used his shoulders to shoot the puck. Photo 2 shows the two brothers pursuing the puck.

Photo 1

Photo 2

The support of the Natural Sciences and Engineering Research Council of Canada (No. A7014) is acknowledged.

MOSFET POWER DEVICES FOR VEHICLE MOTOR CONTROL

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ABSTRACT - This paper concerns the use of MOSFET power transistors in motor control applications. Advantages over present alternatives will be cited and the results of the construction of a MOSFET bridge for motor drive will be discussed.

RÉSUMÉ - Cette communication concerne l'utilisation des transistors de puissance MOSFET pour la régularisation du fonctionnement des moteurs. On indique les avantages par rapport aux solutions existantes et on discute des résultats de la construction d'un pont à MOSFET pour l'entraînement par moteur.

INTRODUCTION

In electric wheelchairs using DC motors, there must exist a circuit which takes signals generated by a joystick or other input device and generates the appropriate voltages needed to drive the motors. These circuits generally fall into two types.

The first type of circuit is a linear power amplifier which would amplify the input signals to a level capable of supplying the motor's current and voltage requirements. Since it operates linearly, it has low efficiency.

The second type of circuit is one in which the input signals are used to vary the duty cycle of a fixed frequency, square wave, voltage signal. This type is called a pulse width modulation circuit, or simply PWM. This new signal is then amplified and applied to the motor which integrates it yielding an effective current as shown in fig. 1. This method has the advantage over the previous type in that the signal applied to the motor is binary in amplitude (rather than linear) and can be realized by components acting as switches. This enables the circuit to have a significantly higher efficiency than the previous type.

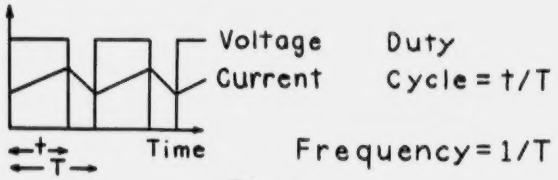

Fig. 1

The disadvantage to this method is that losses are incurred by the motor due to the current fluctuations. Also, there is the problem of an audio whine due to the current fluctuations if the switching frequency is in the audio range (20 Hz to 20 kHz). Thus, one would like to choose the switching frequency to minimize these effects and eliminate the audio whine since it quite annoying.

Overall, this method is more efficient and thus the PWM system is the one predominately used in driving wheelchair motors. This paper will discuss the use of MOSFETs (Metal Oxide Semiconductor Field Effect Transistors) in this type of drive system and the significant advantages they yield relative to designs using other power devices.

CIRCUIT REALIZATION

To achieve bi-directional motor drive in a single power supply system such as in a wheelchair, some implemtation of the topography shown in fig. 2 is used. In operation, the appropriate switches are opened, closed, and pulsed to drive current into the motor in the desired direction. For example, for forward drive switches C and D would be open, B would be closed and A would be pulsed, and similarly for reverse drive.

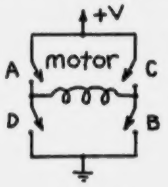

Fig. 2

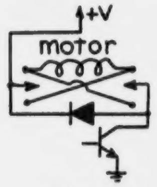

Fig. 3

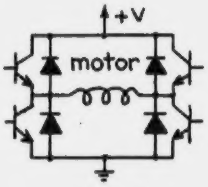

Fig. 4

This operation can be implemented in a number of ways. One such realization currently in use is shown in fig. 3 where relays and a transistor are used. Engaging the relays in the correct manner puts the motor in the desired mode, and the transistor is pulsed to provide the desired effective voltage described previously.

Although quite simple, the circuit suffers from a number of disadvantages. First, the circuit uses relays for direction changes. This is undesireable when used in a closed loop control system because of the time delays inherent in their use. The second disadvantage is that there is the possibility of the relays breaking large motor currents when switching directions. This causes arcing and pitting of the relay contacts leading to eventual failure.

A second realization which is employed in some wheelchairs is the bipolar transistor bridge as shown in fig. 4. Although more complex, this circuit overcomes the disadvantages of the previous realization since there are no inherent polarity switching delays and no mechanical contacts. This is quite an improvement over the previous circuit, but still suffers from an inability to have a switching frequency above the audible range. Thus, an audible whine is generated as described before.

The operating frequency of these bipolar devices has not been pushed out of the audible range because of the relative slowness of the transistors in switching from "on" to "off", resulting in excessive power dissipation if the switching frequency is much higher than 10 to 15 kHz. The nature of the MOSFET is such that it does not suffer from this limitation, and in addition enjoys other advantages over bipolar devices.

COMPARISON

The differences between the two types of transistors can be seen in fig. 5. The bipolar transistor is essentially a current-controlled device. A current must flow from the base to emitter of the transistor in order for a current to flow from the collector to emitter. On the other hand, the MOSFET is a voltage controlled device. A voltage must be applied between the gate to source for a current to flow from the drain to source. As one can see, the gate, source, and drain are analogous to the base, emitter, and collector respectively.

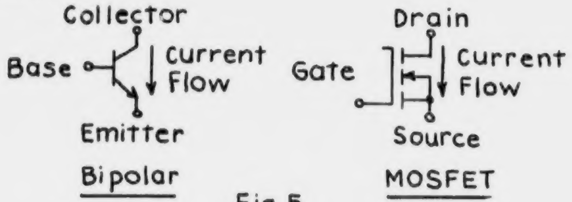

Fig.5

Because of this difference, the MOSFET has a significant advantage. power is consumed in the base-emitter junction of the bipolar transistor because of the current needed at the input to drive the transistor. However, in a MOSFET only a voltage is applied to the input, which consumes no power in the static case since the input of the MOSFET is for all practical purposes an open circuit. The MOSFET thus uses smaller, simpler drive circuitry which increases efficiency, reduces component count, and consequently cost. Also, the diodes shown in fig. 4 of the bipolar bridge are not needed in a MOSFET bridge as shown in fig. 6, because of the MOSFET's construction. Again the parts count is reduced.

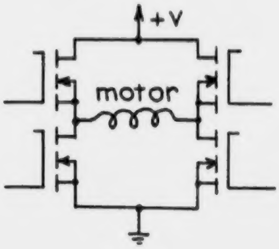

Fig.6

Another very significant advantage of the MOSFET is that it can be switched at higher frequencies more efficiently than the bipolar transistor. Thus, switching speeds in excess of 20 kHz are achieved quite easily which eliminates the audio whine.

To achieve a higher current capacity of the bridge without using a larger, more expensive transistors, one can simply parallel several transistors. However, using bipolar transistors requires additional components to do this, which again wastes power and increases complexity. MOSFETs, however, can be directly paralleled.

Finally, when a power system is designed, it is desirable to incorporate protection circuitry, such as current limiting, to prevent self-destructive behavior. With bipolar devices, small series resistors are usually added, or the wiring resistance is used to sense the motor current, providing a trigger for the protection circuit. Appropriate resistors for this application are expensive, and dissipate power, while using wiring resistance results in poor performance. With MOSFET devices, current limiting is quite simple. the MOSFET is basically a resistor when turned "on" and can be used to implement the resistance needed.

CONSTRUCTION

For the Alexis Wheelchair Technology Testbed project, an all-transistor bridge was needed to implement closed-loop vehicle control. MOSFETs were used because of the preceeding advantages. These bridges are capable of providing 1/2 HP continuously to the motors at an estimated efficiency of 85%. The operating frequency is 23 kHz, and the prototypes measure 5.5"L X 2"W X 2"H. They are able to withstand a continuous direct short-circuit and return to normal operation when the short is removed.

CONCLUSION

In conclusion, it is apparent that the MOSFET has a number of advantages over the bipolar transistor in vehicle motor control. The advantages mentioned are just some of the more important ones. MOSFETs are nearly ideal switches, and are quite easy to design with. Consequently, they deserve consideration by rehabilitation engineers working with power control applications. This work was supported by the Veterans Administration Merit Review Grant "Development and Evaluation of a Wheelchair Feedback Controller".

WHEELCHAIR STYLING: A DESIGN EXERCISE

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ABSTRACT - This paper deals with the integration of styling considerations in the design of wheelchairs, and a specific example of such an effort at the Veterans Administration Rehabilitation Research and Development Center.

RÉSUMÉ - Cette communication traite de l'intégration des considérations d'esthétique industrielle dans la conception des fauteuils roulants et donne un exemple précis d'une telle réalisation faite au Veterans Administration Rehabilitation Research and Development Center.

Most of the personal vehicles that we refer to as "wheelchairs" have pretty much the same general appearance. they are constructed of tubing, usually chromed, have two large rear wheels, and a naugahyde sling seat and back. In the few machines that function as wheelchairs without sharing this design, appearances seem to be an afterthought in the design phase. "Now that it runs, how can we cover up the workings?" Machine styling has traditionally been avoided, perhaps because of an unwillingness to treat a mobility device as anything more than an unavoidable orthosis.

We believe that there is a legitimate human need for devices that are aesthetically pleasing. Consider: we dress ourselves in a fashion that reflects our tastes, when we buy a car, we try to buy one that matches our personalities, and we choose a color and interior finish that we like. Yet when the subject comes around to personal mobility devices, we seem to think that "one style fits all", and that style is the one best suited to use in health care facilities. Whether we like it or not, the image of a wheelchair carries very powerful associations in our society—associations with hospitals, sickness and infirmity. This hardly seems appropriate when you consider that most people in wheelchairs are not "sick", but simply need a mobility aid to get around. it is a part of their lives.

We have examined our thinking in this regard and resolved to change our paradigm. a mobility device to be used in the long term should not be viewed as a temporary aid or refuge, but as a possession, an expression of a person's personality and style, just as a person's clothes and car are. We don't feel we are alone in this evaluation, it seems that there are far more manual sports chairs rolling around than there are wheelchair athletes, and perhaps that is because of the difference in appearance of the sports models. They are smaller, sleek looking, have anodized frame members (chrome intimates that the chair occasionally goes into the autoclave for sterilization) and attractive fabric upholstery. Simply put, they are sportier and sharper looking than an ordinary manual wheelchair. Unfortunately, there is no powered analog to these manual chairs.

When the opportunity to design a new type of powered personal vehicle arose at the Veterans Administration Rehabilitation R&D Center, it was decided that one of the major considerations in its design would be the appearance of the machine. It shouldn't look like a piece of medical equipment; rather it should be attractive, socially unobtrusive, and functional. This prioritization was purposely adopted. many machines have been designed to be primarily functional, and we felt that in this case a special effort should be made to emphasize the other considerations.

The appearance of the Alexis Wheelchair Technology Testbed was the result of this effort, emerging from a balanced approach to the integration of style and function. For example, it was clear from early on that the chassis of this machine would require some housing to protect the batteries and exposed electronics from the elements. rather than dealing with this aspect of the machine last, it was approached in parallel with the development of the rest of the machine. Several approaches were considered, from a monocoque chassis/housing to one employing vacuum-formed plastic panels that would simply snap in place to cover the workings. While it was tempting to festoon this vehicle with "Star Wars"-type gadgetry, this was eschewed in favor of giving the machine a sleek, simple and clean (almost automotive) look.

The prototype was formed of fiberglass. Ordinary procedure would have been to form a wood or metal "plug", then from this generate a mold which would be used to make the final part. However, this procedure is very time-consuming and costly. Since only one part was needed, a single plug was made from closed-cell white styrofoam, reinforced with a fiberglass shell, then used directly to form the part without the intermediate mold step. The finish on the part is a polished polyurethane epoxy paint. The trim lines were added with pinstriping tape to accent the body contours.

A Recaro Idealseat C was specified for the project because it presented an attractive combination of adjustments, comfort and appearance. The shape of the housing was tailored to match this aftermarket automotive product.

Color is another important issue. The color of the seat was limited to relatively few choices. The color of the housing was chosen to compliment that of the upholstery, a light bluish grey to offset the slate blue fabric.

It should be stressed that this is not our final statement of what personal vehicles should look like; every individual is going to like something a little different. It is, however, our first entry in what we hope will be a long line of different styles of personal vehicles.

ADVANCED COMPOSITE DESIGN FOR REHABILITATION APPLICATIONS

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ABSTRACT - Fibrous composite materials provide unique structural design opportunities. This paper discusses the design freedom available in the interaction of materials design, physical layout, and desired performance criteria. An application of composites technology to a wheelchair chassis/suspension implementation is described.

RÉSUMÉ - Les matériaux composites fibreux offrent des possibilités uniques en matière de conception structurale. Cette communication parle de la grande liberté de conception dans l'interaction entre les critères de conception des matériaux, de disposition physique et de rendement désiré. On décrit une application de la technologie des matériaux composites pour la réalisation d'un châssis et d'une suspension pour les fauteuils roulants.

INTRODUCTION

Fiber reinforced plastics have long been a mainstay in industrial products, and have had many applications in recreational, marine and automotive products. In order to meet strict structural performance criteria, the aerospace community has pioneered the use of advanced composite materials, these composites typically consist of aramid or carbon (graphite) fibers imbedded in an epoxy matrix. The adaptation of this aerospace technology by other industries has resulted in an integration of conventional fiber reinforced plastic technology with advanced composite technologies, these hybrids provide a new spectrum of material behavior and design opportunities.

The advances in the composite materials field are being incorporated in many current automotive and marine products, and have had an overwhelming impact in recreational products (kayaks, canoes, tennis and racquetball racquets, fishing poles, golf clubs, etc.) Industrial applications range from high speed machine tools to x-ray equipment and precision instruments.

To date, these materials have been used by manufacturers in some medical equipment, but only in a limited number of rehabilitative applications. The recent use of these materials in many other fields suggests that prosthetic, orthotic, and wheelchair devices might benefit greatly from their use as well.

BACKGROUND

The term "composite" connotes an integration of two or more dissimilar materials to form one single material, often having properties which differ significantly from either of its constituents. Fibrous composites are a class of composite materials in which strong, stiff fibers are imbedded in a soft, elastic, glue-like matrix. The fibers serve as the load-bearing constituent, while the role of the matrix is to bond the fibers together, protecting them from hostile environments and distributing the effect of damaged fibers.

The result of this fiber-matrix combination is an anisotropic material; that is, the properties of the material are directionally dependent, the response of the material to loading will be a function of direction in which the load is applied. Since fibers can be aligned in any direction in a plane, the fiber-reinforced composites are best suited to two-dimensional loading situations such as thin, flat shapes and essentially two-dimensional curved surfaces.

Fibrous composites offer unique opportunities in design, reaching far beyond providing lighter substitutes for more conventional materials. The starting point in design philosophy is to realize the flexibility that this group of materials provides. In contrast to conventional materials, one is not designing with a single material, but with a group of materials having a wide range of properties. By mixing fiber types and by specifying fiber orientation within a specific laminate, one has the freedom to tailor the resultant properties over a very broad range. The most successful solutions will be achieved when this versatility is fully used right from the beginning of the conceptual design phase of the application.

The availability of high specific stiffness (stiffness per weight) and high specific strength are perhaps the two most common reasons for using composites, but their other properties are often key factors in material selection. Their performance in damping vibrations, their resistance to corrosion, high fatigue life, dynamic impact response, impact resistance, toughness and dimensional stability are among other reasons for their use.

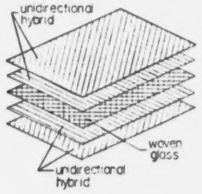

Figure 1. Typical composite laminate consisting of woven and unidirectional layers.

The nature of these materials and the manner in which they are manufactured provide other significant advantages over conventional materials. Since composite components are "built up" (layer by layer, or by individual fiber, figure 1), components can be selectively reinforced in any area of stress concentration or high loading. The components can, and often do, functionally replace multi-part metal assemblies, eliminating many joints, fasteners, and connectors, which are often sources of premature failure.

AN IMPLEMENTATION

Fibrous composite plates are used in the chassis/suspension system of the Alexis Wheelchair Technology Testbed, developed by the Palo Alto Veterans Administration Rehabilitation Research and Development Center. Three rigid vertical 'C' channels support two parallel flexible continuous glass/epoxy, or dynel/glass/epoxy chassis plates. The vertical members serve as mounts for the electric motors and power amplifiers, while the horizontal composite plates act as a spring/damper system, flexibly supporting the seat, batteries, and internal components (fig. 2). A suspension system of some type is necessary for this vehicle since the hard rubber rollers replacing the tires (providing the omnidirectional capability of the wheels), can't provide the shock isolation usually provided by pneumatic tires. This chassis configuration isolates the user from any shock and vibration transmitted through the wheels, and protects batteries, electronics and other components.

The choice of the chassis material was assisted by an electronic spread sheet calculation which compared material thickness and weight with the resulting natural frequency and level of stress for a variety of materials. Development of a preliminary half-scale model of the implementation indicated that one of the three modes (see fig. 3) of chassis deflection was a potential problem. It was felt that any side sway of the vehicle due to bumps would be very uncomfortable, while the fore-aft motion during acceleration and deceleration is common to all vehicles. This led to a decision to stiffen the material in the transverse direction, eliminating that particular deflection mode while still allowing substantial vertical deflection. This was accomplished by adding a nomex core between layers of the material.

Further development of the chassis will be directed at refining the horizontal chassis plates to achieve an optimum ride. The use of fibrous composites makes this refinement convenient: the complexity of a nomex core can be eliminated by orienting a large portion of the fibers in the transverse direction, and the firmness of the ride can be altered by varying the percentage of fibers running longitudinally, or alternatively by mixing in layers of other fibers. Calculations of laminate properties and behavior can be made by graphical methods, hand-held calculator programs, minicomputer software, or thru CAD implementations. The choice of manufacturing method will be dictated by cost considerations and production quantities.

SUMMARY

The use of alternative composite materials in rehabilitative devices is much more limited than in other fields, for no apparent reason. If used effectively, the unusual properties of these materials will often lead to a much more efficient design than possible with other materials. A wheelchair developed by the Veterans Administrataion uses this technology, with anticipated future development specifically utilizing the design flexibility inherent with these materials.

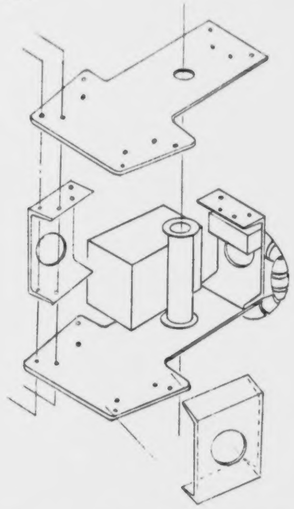

Figure 2. The Alexis Chassis

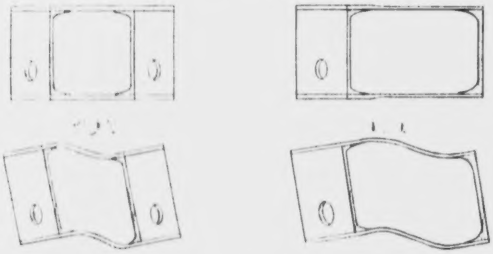

Figure 3. Chassis Deflection Modes

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DESIGN DEVELOPMENT OF A TANDEM BICYCLE FOR INDIVIDUALS WITH AND WITHOUT LOWER LIMB DISABILITY

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ABSTRACT - This paper describes the design development of the Handbike Tandem, a tandem bicycle for the disabled and able-bodied to ride together. Developed at the Palo Alto VA Rehabilitation Research and Development Center, the Handbike Tandem is a spinoff from the single rider arm-powered Handbike design.

RÉSUMÉ - Le présent rapport décrit la conception du Handbike Tandem, un tandem permettant à une personne handicapée et à une personne non handicapée de voyager ensemble. Mis au point au Palo Alto VA Rehabilitation Research and Development Center, ce tandem est un dérivé de la bicyclette à bras monoplace.

INTRODUCTION

The Handbike Tandem, to be shared by individuals with and without lower limb disability, is a natural extension of the development of the single rider arm-powered Handbike (1,2). Both the Handbike (formerly called the "Para-Bike") and the Handbike Tandem are bicycles offering the exhilaration and sense of freedom of being on two wheels.

Bicycling, Recreation and Integration

Bicycling is a revitalizing activity. Whether for recreation, sport or transportation, the physical exertion, the sensations of motion and balance, and the opportunity to share a popular sport with friends, provide the bicyclist with fitness, a clear mind and a renewal of spirit and enthusiasm that will carry over into the other activities of daily living.

By its nature, the Handbike Tandem is a vehicle of integration. The riders move as one, balancing and powering the bicycle. As a team, their progress is defined by their ability to sense each other's motion and respond with the appropriate power and control.

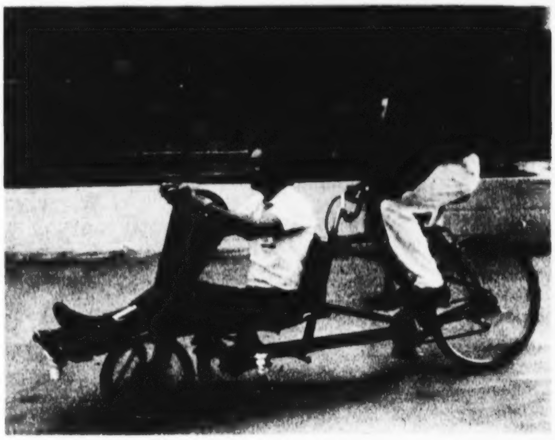
Community Awareness

Within the community, the Handbike Tandem teamwork may set an example, heightening awareness and drawing attention to needs we all share - to be mobile and to participate in recreation with our family and friends (3).

DESIGN FEATURES

Conceptually, the Handbike Tandem consists of merging a Handbike in the front (Figure 1) with a standard bicycle in the back. The front rider drives the front wheel with arm power, and the rider in the back drives the back wheel with foot power. Both riders have access to the steering of the front wheel. The rider in the back sits high enough to comfortably see over the front rider, so both have a clear view ahead.

As on the Handbike, the front rider's drive system incorporates hand cranks and a chain linkage to the front wheel, using standard bicycle components. On both the Handbike and the front position of the Handbike Tandem, powering and steering are done with the upper body. The drive input essentially replaces the handlebars, causing the drive system to turn with the front wheel. To minimize the possible confusion of powering forces influencing steering, the hand cranks move in unison, unlike standard foot cranks. In this case, equal propulsive forces to each crank deliver no torque to the steering. This improves steering control, and reduces overall effort.



Remote steering of the front wheel is also available to the rear rider. This is accomplished through a tie rod which links the rear rider's handlebar steering to the front fork crown. A similar remote dual steering system was employed on a tandem built in the 1890's.

The front rider backpedals to activate a Sturmey Archer hub brake at the front wheel. The back rider has standard hand levers to control a hub brake at the back wheel and a caliper brake at the front wheel.

The back rider is in a good position to help stabilize the bicycle when at rest as foot placement on the ground is approximately midway along the length of the bicycle. Sidewheels are located adjacent to the front rider to assist in balancing when the bicycle comes to a stop. The sidewheels remain up off of the ground for two-wheeling, and may be preset (from zero to 20 degrees) to allow the desired lean for cornering. A sprung suspension provides shock cushioning at touchdown. The sidewheels may also fasten down for four wheel maneuverability indoors or to provide a stable platform for transferring to and from wheelchairs.

A folding crank tower provides easier access during transfer. The crank tower pivots just above the front wheel and folds onto the legrest, so that the rider may transfer onto the seat first and then lift a leg over the folded crank tower to the other side of the legrest.

In the interest of independence and equality, this first prototype of the Handbike Tandem was designed to allow it to be ridden alone by one rider in either the front or back position. Both riders have power input, steering and brakes, and a means for stabilizing the bicycle when it comes to a stop.

BALANCING A BICYCLE BY STEERING

To maintain balance, a bicyclist may either lean or steer a bicycle. The leaning and steering are inextricable coupled in the dynamics - if one happens, so does the other, or the bicycle tips over. It is common experience that a bicycle may be ridden without hands. The rider balances and steers by causing the bicycle to lean.

The Handbike and the front position of the Handbike Tandem operate at the other extreme. The rider controls balance, lean and vehicle direction simply by steering. Often contrary to the casual bicyclist's experience, once a bicycle is leaning and turning, a change in vehicle direction may be accomplished by first turning the front wheel in the opposite direction. This leans the bicycle in the proper direction and the steering follows. Many bicycle riders are unfamiliar with this characteristic, as turns are typically initiated by leaning the bicycle, and not consciously by steering in the opposite direction.

This natural characteristic of bicycle dynamics is particularly advantageous for individuals with limited trunk stability. Once situated in the seat, one does not have to lean relative to the bike, as steering alone controls balance and change in direction.

The Handbike Tandem is constructed using standard custom bicycle frame building technology. High strength chromium molybdenum steel tubing is mitered and the joints are brazed without lugs. With this process, frames are relatively easy to fabricate, allowing a quick turn around in prototype development, and flexibility in incorporating design modifications.

FURTHER DEVELOPMENT

The first prototype of the Handbike Tandem, described in this paper, was completed by June, 1983. The conceptualization and initial design phases of the second prototype are nearing completion, and the building will soon begin.

Although the first prototype has demonstrated the feasibility of the tandem concept, there are improvements to be made and alternative drive and steering configurations to be tested on the next prototype. For instance, on the first prototype, both riders have access to the steering at the same time. The riders must communicate to decide who is going to be in control. This cooperative steering may cause problems in an emergency situation, and will not be incorporated on the next prototype.

The option of arm and foot power for the front rider is under consideration for the next prototype. This will allow riders to use whichever limbs are functioning to help provide power, and increase the market potential to include able-bodied riders who would like to use both arms and legs. If a vehicle is also appropriate for able-bodied riders, then riders with a disability are not as likely to feel that they must be treated differently because of their disability.

ACKNOWLEDGEMENTS

The Handbike Tandem has been developed at the Palo Alto Veterans Administration Rehabilitation Research and Development Center in conjunction with the University of British Columbia Athletic Department, under sponsorship from the British Columbia organization for the 1981 International Year of the Disabled Person. Evaluation of the Handbike Tandem and earlier versions of the Handbike is continuing in Vancouver, British Columbia.

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SELF PROPELLED ATHLETIC VEHICLE

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ABSTRACT - From my experience, having viewed wheelchair olympics and other handicapped athletic events, I find the present wheelchair design does not adequately serve the needs of the handicapped athlete. I feel that I have developed a Self Propelled Vehicle that will meet a number of these needs.

RÉSUMÉ - Après avoir vu des olympiades et d'autres événements sportifs pour handicapés, j'en suis venu à la conclusion que les fauteuils roulants actuels ne sont pas conçus pour bien répondre aux besoins des athlètes handicapés. Je crois avoir mis au point un véhicule autopropulsé qui satisfera à un certain nombre de ces besoins.

My approach to this subject will be from the position of a teacher of movement in which I view the User, in this particular model a paraplegic with full use of upper torso, and Vehicle as a fused unit.

Problems with conventional chair:

1) Upright conventional seated posture is constantly maintained. Very little allowable flexion/rotation/stretch.

2) The legs themselves play no active part in movement of any kind.

3) Overall manoeuverability is confined to the chair itself.

At this point I would like to add that a good many of these problems stem from the trying to fit user and vehicle into conventional game systems. With new vehicles providing a broader range of physical possibilities, I am sure that game designs will change to.

Proposed vehicle:

In thinking of a corporeal correlate to vehicle capability, I would ask the reader to imagine a downhill slalom skier placed horizontally on a gymnasium floor but maintaining the same postural attitudes and dynamics utilized in the normal play of this event. The skier depends on two points of rotation and three points of flexion/extension. The two points of balance would be coccyx and heel, the central point of balance centered through coccyx/sacral region. Forward/backward motion(A) and pivot(B) would be through use of poles (impossible in this position) so we substitute hands(A) and elbows(B). The ability to achieve a 'full back layout' with torsion would facilitate tight cornering with elbow pivot and recourse to egg shape would give maximum speed. Much of this work is accomplished through the full use of the external obliques, latissimus dorsi, trapezius, deltoid and pectoralis major muscle groups. The legs would be brought into play, being mechanically flexed/extended to serve as counterbalance and guidance in conjunction with upper torso work.

The device which I am proposing is a mechanical extension of the ideas which I have outlined. The prototype will be ready for demonstration at this conference.

DEVELOPMENT OF LIGHT WHEELCHAIRS WITH HYBRID COMPOSITE

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ABSTRACT - Attempt was made to develop a wheelchair whose frame were made of hybrid composite pipes and special joints. The weight of the wheelchair is 9.85 kilograms. The strength of the wheelchair was examined through practice runs and loading tests.

RÉSUMÉ - L'effort a été fait pour développer un fauteuil roulant légér dont le châssis a été composé tuyaux en composite hybride et joints spéciaux. Le poids du fauteuil roulant est 9.85 kilos et son intensité a été verifiée par la course pratique et l'expérimentation de chargement.

INTRODUCTION Muscular Dystrophy Associations of Japan reports that the majority of wheelchair users want wheelchairs that are "more stable and, among other things, more light-weight so that they can be easily carried and easily put into trunks of cars by women." Made of steel, regular wheelchairs currently produced in Japan weigh about twenty kilograms. Recently, a new type of wheelchair, made of aluminum alloys and weighing thirteen kilograms, has started to appear on the market. To meet the ever-increasing demands of users, our team (Industrial Products Research Institute, Nitto Boseki, Co., Ltd, Toray Industries, Inc. and Mitsui & Co., Ltd.) have been collaborating since 1979 in the research and development of a portable, collapsible wheelchair weighing under ten kilograms.

MATERIALS Aluminum alloy, GFRP and CFRP were considered as weight-reducing materials, The comparison of the properties of these materials are shown in Table 1. Aluminum alloy has specific strength (approximately twice that of steel); therefore, frame weight will be reduced to almost half that of steel, and total weight will be reduced only up to 35%. Fiber reinforced plastics (FRP) are suitable materials for weight reduction. The relatively low Young's modulus of GFRP will result in great deformation when using the wheelchair frame. CFRP has a low specific gravity, high strength and high Young's modulus; therefore, it is the optimum light-weight material. However, CFRP's disadvantages are high cost, low fracture deformation and brittleness. Considering the above characteristics of the various materials we adopted a hybrid composite of C/G-FRP which has both the high Young's modulus of CFRP and large elongation of GFRP. With respect to the method for molding the pipe we decided upon filament winding (FW) because it enables the fibers to be used continuously, and the strength ratio of the axis/hoop may be selected freely as well as obtaining a high volume fraction of fibers.

Table 1. Mechanical properties of various materials.

	Strength	Elastisity	Specific strength	Specific elasticity
	kg/mm2	kg/mm2	X1000000 mm	X1000000 mm
Steel	60	21000	7.62	2.67
Aluminum	40	7500	14.8	2.78
GFRP (70wt%)	38	2700	19.7	1.40
CFRP (60wt%)	45	7500	30.6	5.10

DESIGN OF THE EXPERIMENTAL WHEELCHAIR The basic frame configuration of the new folding wheelchoir is a combination of the C/G-FRP-FW pipes and CFRP joints with a single brace. The wheelchair is collapsible with separate right and left frames which are connected to the seat and brace pipes. The brace pipes are then connected to the brace and seat pipes by free revolutional joints and bolted at the point of intersection. Strength criteria were decided upon by the following methods.

(1) Evaluation of the strength of the member pipes.

Static load (60kg) is applied on the seat. Maximum stress is at the center of the brace and should be 1/4 of the fracture stress of the C/G-FRP-FW pipes.

(2) Evaluation of overall rigidity.

Maximum strain at the center of the brace should be equivalent to that of steel. Both types of wheelchairs were designed by three-dimensional structural analysis. For pipe strength, Experimental Wheelchair NO.1 was made with C/G-FRP-FW pipes having an outer diameter (OD) of 22mm and inner diameter (ID) of 19mm for the frame and an OD of 28mm and ID of 25mm for the brace. (right, photo1) 1)

For overall rigidity, Experimental Wheelchair NO.2 was made with C/G-FRP-FW pipes having an OD of 28mm and an ID of 25mm for the frame and an OD of 29mm and an ID of 25mm for tne brace. (center, photo.2)

Experimental Wheelchair NO.1 and NO.2 were both designed with a single brace. Concerning handling ability, the single brace presents difficulty when the wheelchair is folded. To solve this problem, we decided to adopt a double brace for Experimental Wheelchair NO.3 (left, photo.1) 2) The use of a double brace obviously has more strength and stiffness then those "single-brace" systems used in Experimental Wheelchair NO.1 and NO.2. The double brace also enabled us to use the brace pipe with the same diameter as the frame pipe. In addition, the seat pipe is mechanically balanced at the front and rear posts when the wheelchair is in the normal position.3)

Experimental Wheelchair NO.4 (photo.2) was redesigned in line with comments received duaring the special evaluation,4) and several improvements in wheelchair design were achieved.

(1) Adjustable location of rear wheel axle.
(2) The length of the arm rest is shortened to allow for easy transfer.

The weight distribution of Experimental Wheelchair NO.4 is shown in Table 2 as compared with a regular wheelchair.

Table 2. Weight distribation of the wheelchair.

	Standard (Steel)	Experimental (C/G FRP)
Frame	8.0 kg.	2.8 kg.
Wheel	6.0	3.75
Caster	3.2	1.2
Foot rest, Sheet, Brake	3.1	2.1
Total	20.3	9.85

CONCLUSION We developed a unique hybrid C/G-FRP-FW pipes and special joints in a new concept. With the introduction of the new design of the frame construction light-weight, hybrid-composite wheelchairs of 9.85kg were produced. The strength and safety of the wheelchairs were tested in practice runs and loading tests, and the wheelchairs were found to be sufficiently durable for daily use. We believe that our light-weight wheelchairs will be welcomed by users and attendants.

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Photo. 1. Experimental Wheelchairs NO.1, NO.2, and NO.3 from right to left.

Photo. 2. Final type of light wheelchair and weight is 9.85 kilograms.

MICROCOMPUTER IMPLEMENTED ADAPTIVE CONTROLLER FOR ELECTRIC WHEELCHAIRS

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ABSTRACT - The design of a microcomputer control system for adaptively regulating in a time-optimal mode the velocity of an electric wheelchair is described in this paper. The system represents an improvement over previously reported ones because it adapts to load variations.

RÉSUMÉ - La présente communication décrit la conception d'un système de contrôle géré par micro-ordinateur permettant de régler au besoin dans un mode de temps optimal la vitesse d'un fauteuil roulant électrique. Le système est supérieur aux précédents car il s'adapte aux variations de charge.

I. Introduction

This paper describes the design and simulation of an adaptive microcomputer controller for electric wheelchairs which adapts the control to parameter variations thus providing optimum time response to velocity command inputs.

The adaptive controller would be ideally suited for use in chairs with automatic guidance capabilities. However, it is also possible to use it in conventional electric wheelchairs in which it will improve the performance by providing a faster response to the user's commands and making the system unconditionally stable. The design of an adaptive controller is now technically feasible due to the advent of single chip microcomputers and VLSI systems. The adaptive controller concept is applicable to automatic guidance as well as to conventional guidance.

The adaptive controller represents an improvement over existing ones [1,2] because it responds to velocity commands in an optimum way, adapting the controller parameters to varying load inertia and friction, which are important factors in wheelchair dynamics but not necessarily in other types of velocity control systems such as automated public transportation systems. In a wheelchair, the system's inertia can vary by maybe as much as 100%, depending on the person using the chair; friction also varies over a wide range, depending on the type of surface over which the chair is being used. Another parameter with wide variations is the center of gravity which depends on user's size and position in the chair.

II. Design

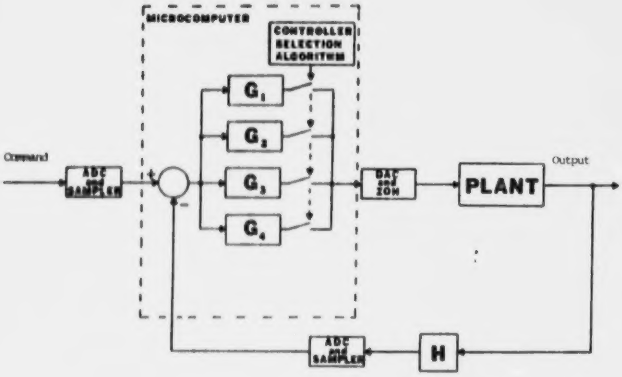
The control system in an electric wheelchair involves the utilization of feedback to force the actuators to respond appropriately to commands that are generated by the guidance system. The guidance system could be automatic or human controlled.

For the electric wheelchair, the actuators that are to be controlled are direct current (dc), permanent magnet motors, and the major control encountered results from the time variations of the motor load characteristics. Load characteristics vary because of a number of factors which include changes in the type of surface being travelled upon and variable positioning, or mass, of the rider. The result of these changes is significant degradation of the time response of the motors to velocity commands. In order to alleviate these problems, it is necessary to utilize adaptive control concepts such that the system is capable of detecting parameter variations and making adjustments such that acceptable performance is maintained at all times.

A microcomputer control system has been designed for adaptively regulating in a time-optimal manner the output velocity of a dc motor which is subjected to substantial variations in load inertia and load damping [3]. The system has been designed for application to the electric wheelchair control with an expected potential for aiding the solution of the automatic guidance problem.

The algorithm has been developed with the computational restrictions of the application in mind. The coefficients for the controllers have been determined in an off-line design procedure which produces both the necessary coefficients and their regions of applicability. A technique based on pattern recognition has been developed for the real-time selection of the appropriate set control coefficients based on least squares estimates of the motor's variable load parameters.

This work progressed in five major phases. First, an examination of the electric wheelchair guidance problem was undertaken and the specific difficulties associated with successfully solving the guidance problem were studied. Second, an analytical model of the electric wheelchair was developed. Consideration was given to the effects of the casters on the motion of the electric wheelchair and the effect of passenger positioning. Simulations and experimentally measured results were obtained to validate the developed model. Next, a variable structure adaptive controller (VSAC) was designed. The block diagram of the control system is given in Figure 1. A controller selection algorithm, stored in PROM, determines what controller is optimum for a given load inertia and load damping coefficient, and that particular controller is selected. The controllers are all of the modified PID type.



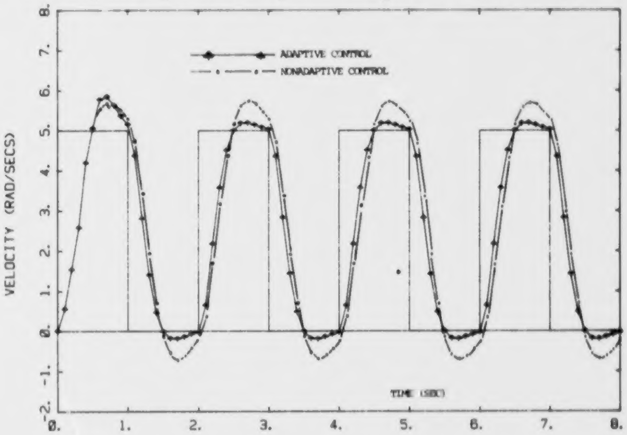
Using state space and optimal control techniques a data set containing load inertia and damping covering the expected range of values for normal operation of the wheelchair was generated [3]. A stability study indicated that for all possible combinations of these parameters a stable time optimal (i.e., a controller capable of following a velocity command in minimum time) PID controller can be designed.

The remaining problem consists of determining the necessary number of controllers for the VSAC and of identifying in what parameter region the chair is operating at a given instant.

To develop the desired regions, cluster analysis techniques from pattern recognition theory were used [4]. The first requirement of any clustering algorithm is the specification of a measure of similarity. For our problem, two similarity measures were specified, with a priority system between the two measures. For two pair of load inertia, J, and damping, B, values to belong to the same region, they should be stabilized by the same control vector, and second, this control vector must also satisfy a specified system performance criterion for the two pair. The algorithm to perform the clustering process was developed in [3].

The next step of the design was to develop a procedure for the real-time identification of the region in which the system is operating. Once the region is identified, the appropriate controller is selected from memory and applied to the control of the system. To separate the regions and perform classification, a mean squared error approach was used [3]. During the implementation of this procedure it was realized that samples close to a boundary which are incorrectly classified still produce acceptable performance in the sense that a stable operation with a relaxed performance results. Using these techniques and the parameters specified in Table I, a variable structure, velocity controller for the electric wheelchair was designed.

A total of four controllers was required to maintain stability and to keep the performance variations less than 10% within a given region. A 10% degradation in performance was allowed such that the number of required regions could be made as small as possible. A FORTRAN simulation package was developed in which the propulsion system (motor-gear box-load) was modelled as a second order system, the values of armature current and shaft speed were used as inputs for the controller selection algorithm which determined the region of operation and then selected the appropriate controller for the determined values of inertia and friction. A worst case of pulse commands was chosen (from zero to full speed and vice versa in zero time). The simulation results for J_L=15.0, B_L=0.1 units with an initial controller corresponding to J_L=2, B_L=0.05 are shown in Figure 2. Notice the improved response provided by the adaptive controller.



The hardware and assembly language software for the system have been designed and a bench test system is being implemented. It is expected that test results will be available early in 1984.

TABLE I - MOTOR PARAMETERS

K_T=.054 ft-lb-s^2 , K_V=.073 Vs

R_a=.13Ω , L_a=.73 mh , N=41

J_B=.00052 ft-lb-s^2 , B_m=.00025 ft-lb-s

$0 \leq J_L \leq 0.6$ ft-lb-s^2 , $0 \leq B_L \leq 0.1$ ft-lb-s

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USER INTERACTIVE ADAPTATION OF THE ELECTRICAL WHEELCHAIR CONTROL INTERFACE

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ABSTRACT - By changing the control stick sensitivity and force characteristic interactively the wheelchair driver can adapt the vehicle's behaviour to subjective needs and preferences. We developed a microprocessor-driven interface for this purpose. This paper describes methods, results of driving experiments, and experiences.

RÉSUMÉ - En modificant de façon interactive la sensibilité et les caractéristiques de force du levier de commande, le conducteur du fauteuil roulant peut adapter le comportement du véhicule à ses besoins et préférences subjectives. Nous avons mis au point à cette fin une interface à base de microprocesseurs. Cette communication décrit les méthodes, les expériences et les résultats des essais de conduite.

INTRODUCTION

The conventional control interface to the electrical wheelchair consists of a two-axis control stick, centered by an arrangement of prestretched strings (linear or progressive characteristics). The control signals for velocity and heading are derived from resistance potentiometers attached to the control stick axes. These signals are then filtered and transformed by analog circuitry before they enter the power drive circuits of the vehicle.

In many cases, this control interface is not well adapted to the severely handicapped wheelchair driver. Special problems arise with the rear-wheel-driven indoor-chair in respect to safe and comfortable manoeuvrability. Considering those drivers who manually control their wheelchair by means of a control stick, some deficiencies may be countered by appropriate methods of digital control signal transformation and programmed two-axis force characteristics.

INSTRUMENTATION

We devised, developed and tested a wheelchair-borne instrumentation for control signal transformation and force characteristics generation, as shown in Fig. 1. The command inputs for velocity (v_{COMM}) and heading (φ_{COMM}) are transformed per program into new input values (v_{INP} and φ_{INP}) for the conventional wheelchair electronics as well as into control stick torque values (M_v and M_φ). The resulting velocity and heading values (v_{RES} and φ_{RES}) are obtained by summing and subtracting the rotational speed of the two driving wheels (n_R and n_L) as measured by one tacho-generator on each axis. The torques M_v and M_φ are applied to the control stick individually by one small dc-motor attached to each axis. We fitted an Ortopedia UE 924 wheelchair "off the shelf" with this instrumentation. Figure 2 shows samples of the kind of control signal transformation functions and control stick force generation functions which we use for experimentation.

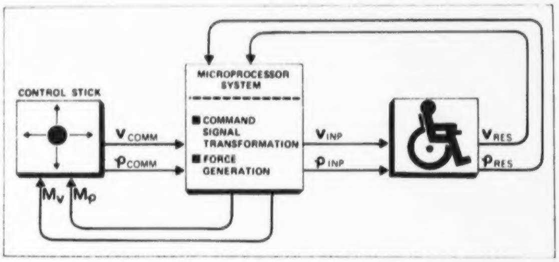

Figure 1: Signal flow for the experimental wheelchair

Generally these functions are generated by using a large number (up to 64) of look-up-tables with 8 bit resolution, but variables may also be interrelated as in the case of directional control. Here the program interpolates between two prechosen heading functions related to minimum and maximum velocity (see $\varphi_{INP} = f\ (\varphi_{COMM}, v)$ - diagram in Fig. 2). For our experiments we fitted a panel with 8 pushbuttons and a 16-character liquid crystal display to the control stick console. The driver or an accompanying person determines the signal transformation and force functions (as illustrated in Fig. 2) by choosing a variable (say backward heading control) and picking one out of five characteristics. Thus a rather large variety of control signal transformation and force generation characteristics is available from which a set of functions can be chosen interactively for a given situation.

EXPERIMENTATION

In order to investigate the new possibilities of configuring the driver-wheelchair-interface in the described manner we carried out driving experiments at the St. Lucas Rehabilitation Center at Hoensbroek, The Netherlands. It was our purpose to a) adapt the control stick deflection force characteristics as well as the control sensivity to individual preferences and arm-hand motor disabilities and b) evaluate adaptation results by objective measurements. Volunteers for our experiments were several handicapped with spinal lesion of different degrees of severity. We standardized the

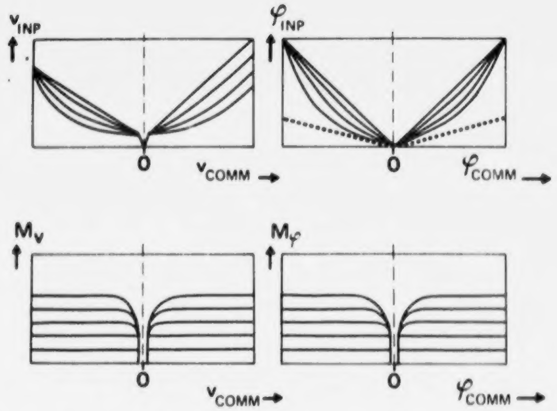

Figure 2: Transformation functions for the generation of input signals and forces from command signals (a sample set)

driving conditions and asked the volunteers to drive a) a 20 m long straight line forward and backward without turning and b) a rectangular circuit of 15 by 10 m with three kinds of obstacles: a narrow door, 5 slalom poles, one curb - all on the hard, flat ground of a gymnasium. The procedure was as follows: We adjusted the deflection forces in both axes (in some cases we used asymmetrical functions for the lateral movement of the hand), selected a set of signal transformation functions, asked the driver to go on the course for several minutes, plotted the data (an example is given in Fig. 3a and 3b), and repeated the procedure with the same configuration (for statistical reasons) or with changed parameter values. The goal of the step by step adaptation was to reduce the variability in both the control error and the control effort.

DISCUSSION

Fig. 3a and 3b shows an example for the influence of lateral force characteristics on heading control. Both error and effort can be reduced significantly, if the force characteristics are well adjusted to the individual's motor abilities. We show this example because the aspect of force adaptation proved to be a major factor in the interface adaptation process. It also helped to improve the inherent direction reversal problem caused by the caster wheel constellation, which nevertheless is quite apparent in Fig. 3. In order to improve the manoeuvrability in low to medium speed situations a careful tuning of velocity and heading functions was necessary. Although each adaptation procedure is driver dependent we successfully employed some general rules: directional (heading) sensitivity should be slightly degressive (overproportional) for small deflections and very low speed (to improve vehicle reaction), becoming less and less sensitive with increased speed. At the same time velocity sensitivity is progressive with a rather flat curvature in the low speed region. The interdependence of velocity and heading signal transformation proved to be one of the main assets of the programmable interface. Further experimental data indicate that the availability of a user interactive interface to the wheelchair helps to adapt the driving characteristics to the handicap and subjective preferences.

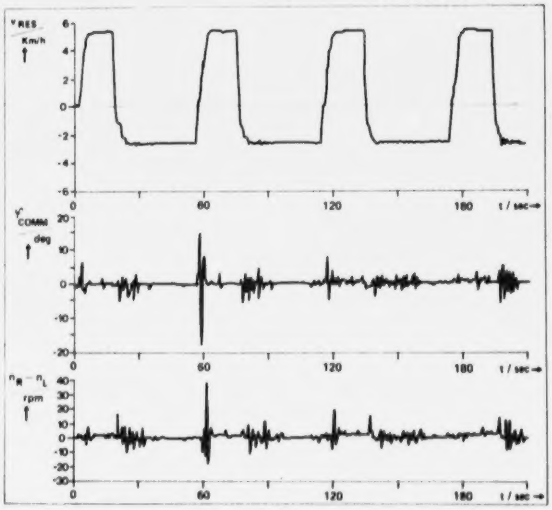

Figure 3a: Recordings from a straight line driving experiment: resulting forward velocity, heading command (positive angular values are deflections to the left, negative to the right), and resulting heading, expressed in difference of right minus left wheel revolutions per minute. Small lateral deflection forces were used (2N, 0.25Ncm)

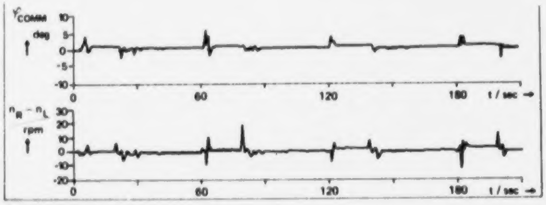

Figure 3b: In contrast to Fig. 3a the lateral deflection forces were raised to 8 N, 1 Ncm resp.

ACKNOWLEDGEMENTS

We thank Mr. Bougie and Mr. Reep of the Lucas Rehabilitation Center at Hoensbroek for their support and advice. The project was generously supported by Ortopedia GmbH, Germany.

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PROPORTIONAL-INTEGRAL FEEDBACK CONTROL FOR POWERED WHEELCHAIRS

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ABSTRACT - The need for a feedback control scheme for powered wheelchairs is discussed, with emphasis on the advantages of proportional-integral control strategies, and the implementation and evaluation of a microprocessor-based wheelchair feedback controller.

RÉSUMÉ - On discute de la nécessité d'un système de régulation à rétroaction pour les fauteuils roulants motorisés en mettant l'accent sur les avantages des systèmes de régulation proportionnelle-intégrale et sur la réalisation et l'évaluation d'un régulateur par rétroaction pour les fauteuils roulants en utilisant un microprocesseur.

Powered wheelchairs generally have two powered wheels and two passive casters that support the weight of the front of the vehicle. These casters are the source of many powered wheelchair steering problems. Two classic examples illustrate these problems: first, steering on a side slope, where the freedom of the casters to change orientation allows the vehicle to veer down the slope, requiring repeated steering corrections on the part of the driver, and second, starting the wheelchair in a new direction after stopping. In this latter case, the driven wheels must supply the force necessary to rotate the casters to their new orientation as well as propel the machine in the new direction. Both of these examples are cases in which the driver must steer in a direction other than the intended direction of travel in order to correct for the caster behavior. Certainly this behavior is annoying and taxing for the driver. A means of eliminating this burden on the driver would be welcome, and a properly designed feedback controller provides such a means.

A feedback controller is one which "feeds back" information about the behavior of the physical system to the command input, using this information to somehow modify that command. For example, a command may be sent to a motor to begin turning at a given speed. Should the motor be more heavily loaded than normal, it would begin turning more slowly than desired. In a feedback system, the speed of the motor would be measured, and the difference between the intended and actual speeds (the error) determined, and this information used to "turn up" or "turn down" the command input to correct for the load. This is the same thing that a powered wheelchair operator does to correct for a load, such as casters pointing in the wrong direction, or a side slope. The difference is that with a feedback controller, the driver is blissfully unaware that this correction is taking place: (s)he need only indicate the direction of desired motion, and the controller takes it from there.

Broadly speaking, most powered wheelchair controllers are "open loop" (figure 1); that is, a command is entered, amplified and fed to the motors, but no note of the resulting motor action is taken. Some work has been done with feedback controllers for power wheelchairs, in fact, at least one such controller is commercially available (though its performance is hampered by the use of relays in its power stage). These devices measure motor or wheel motion by some means, calculate an error signal, then multiply this error by some constant value (called the "gain") before combining it with the incoming command to control the motors. Control engineers call this type of system a "Proportional Feedback" control system, because the correcting value combined with the command is always proportional to the difference between the desired and actual motor speeds.

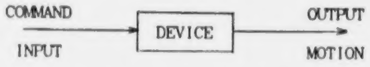

figure 1: An Open Loop System

As much an improvement as proportional feedback control is, it still has some serious limitations. Corrective action is either too weak to completely correct the error, or, if it is strong enough, the system is jerky, with very little slack allowed for smooth accelerations. What is needed is a controller that not only acts strongly to correct errors, like a proportional controller, but which is smoother in its action, spreading it out a bit to prevent jerkiness. A proportional controller can't do this, because it is always acting on the situation that exists at each instant—it can't remember errors that happened before to correct them more slowly. To do this, we need to add some "memory" to the controller, and we do this in the form of an "integrator" (figure 2).

A true integrator accumulates all the signals it sees, positive and negative, and adds them up continuously. If we integrate the error value in a feedback control system, and use this longer term error signal as part of the command correction, we can get the smoother behavior desired. Consider what happens: a command is sent to a motor to

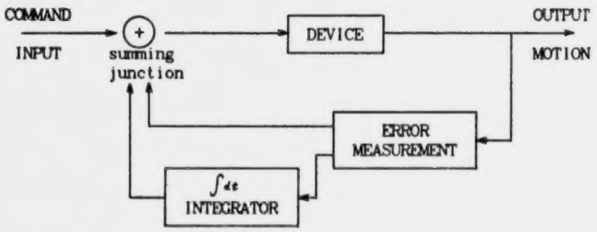

figure 2: a Proportional-Integral Controller

start turning at some speed. The motor can't physically actually start turning instantaneously, so the difference between the command and the actual motion starts out immediately large. This makes the proportional part of the controller want to put out an immediately large correction; if we set the gain of the feedback high enough, this will make the motor (and, in our hypothetical case, the wheelchair) start jerkily. The integrator will start accumulating error signals (figure 3), and this will affect the command input more and more with time. The trick in a real system is to balance the strengths of these two types of behavior so that the system in question will reach a state of zero error in a reasonably short period of time.

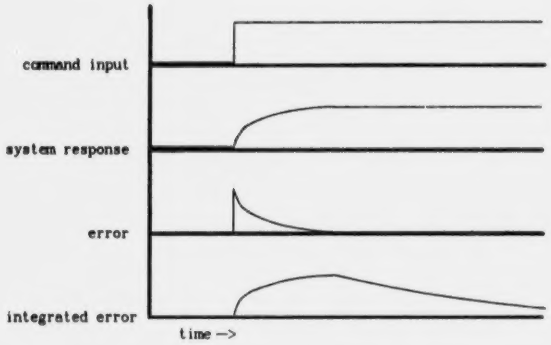

figure 3: System Behavior (Open Loop)

The proportional-integral (PI) controllers developed at the VA Rehabilitation Research and Development Center are based on microprocessor technology. This is not necessary for implementation of PI control; it can readily be done using discrete analog circuitry. However, for the purposes of evaluation of a wheelchair using this controller, it is desirable to be able to change the behavioral characteristics of the machine quickly and repeatably ; this is difficult when working with an analog device, because of the susceptability of discrete components to variances due to ambient conditions. Our digital controllers have their programs and operating systems in ROM, with system variables (integration period, proportional gain, integrated gain, PWM frequency, deadzone width, etc.) stored in non-volatile RAM. Thus, one need only plug in a terminal to alter these parameters in a completely repeatable fashion. The first controller was fabricated for the Center's Alexis Wheelchair Technology Testbed; the second controller is functionally identical, and is mounted on an Everest and Jennings 3N. Both of these devices use the solid-state power amplifiers necessary for closed-loop control applications. The E&J 3N is used for controller evaluation so that its users are operating an essentially familiar vehicle, allowing them to concentrate on its operating behavior rather than having to learn an entirely new machine.

The evaluators can be divided into three groups: a "test pilot" group that is developing some expertise in working with different control configurations, a group of experienced wheelchair users, and a group of relatively new users. The test pilot group acts as a team of "friendly adversaries" for the development engineers, while the two other groups balance the first group's potential for "test pilot syndrome": the ability to fly (or drive) nearly any machine given to them.

Preliminary results with testing and evaluation indicate that PI controllers may well provide an unprecedented level of agility in powered personal vehicles. Further information on this work (power amplifier design, controller design, feedback algorithm, etc.) is available by contacting the investigators. This work is supported by Veterans Administration Merit Review Proposal "Development and Evaluation of a Wheelchair Feedback Controller".

A PROPORTIONAL SPEED CONTROLLER FOR USE WITH PERMANENT MAGNET DC MOTORS

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ABSTRACT - A solid state, two channel, proportional speed control is described which uses pulse width modulation. The control input allows direct connection to a four-quadrant potentiometer joystick. Two output channels provide independent speed control for motors up to 1/6 HP (124 W). Controller parameters can be adjusted to optimize the power/cost ratio for a wide variety of applications.

RÉSUMÉ - On décrit une commande à semi-conducteurs, à deux voies et à vitesse proportionnelle qui fait appel à la modulation de la largeur d'impulsions. La prise de la commande peut recevoir directment un "manche à balai" potentiométrique à 4 quadrants. Deux voies de sortie permettent de commander indépendamment la vitesse de moteurs allant jusqu'à 1/6 H.P. (124 W). Les paramètres de la commande peuvent être réglés de façon à optimiser le rapport puissance/coût pour une vaste gamme d'applications.

Introduction

In a study of the needs of severely disabled children, it has been determined that increased independent mobility is an important factor [1]. It was assumed that the provision of a simple "add-on" power unit, which could be attached to a wheelchair, would satisfy this need. This led to the development of the Mobility Power Unit (MPU), a friction drive electric wheelchair propulsion unit which could be attached to a standard wheelchair. Control was provided by an earlier version of the DC Motor Controller (DCMC) [2]. The DCMC has since been redesigned to act as a general purpose permanent magnet DC motor speed controller.

The Design

The DC Motor Controller (DCMC) is a two channel, completely solid state, pulse width modulated (PWM), motor speed control. The control input allows direct connection to a four-quadrant potentiometer joystick. Three trim potentiometers are used to match the dynamic range of the PWM circuit to the output of the joystick potentiometers. Such matching assures smooth variation of speed over the full dynamic range of the controller. One of the trim potentiometers acts as maximum power output adjustment so that less than full speed operation can be provided during operator training.

For a particular application, the power transistors, base drive resistors, switching-aid networks, and dynamic braking resistors have to be selected. Formulae which consider motor armature resistance, motor electrical time constant, maximum permissible motor current, and maximum motor current demand are used to specify the appropriate components. The PWM oscillator period is adjustable to assure smooth proportional control with motors whose electrical time constants range from 0.2 ms to 2 ms. This range can easily be extended by changing a timing resistor. The maximum motor current required is the basis for choosing the output transistors. In general, the greater the current output specification, the more expensive are the transistors. In applications where a maximum current output of 14 Amps is sufficient, all eight power transistors can be purchased for a total of \$25. If 30 Amps per channel is required, appropriate power transistors cost \$125 total. Once the maximum current output and the power transistors are specified, the remaining electronic components are sized according to a design recipe [3].

Maximum vehicle speed is a function of motor and/or battery voltage selection. Because of the wide availability of 12 V lead-acid batteries, the DCMC is typically configured for operation with a 24 V nominal, centre-tapped, battery supply. However, the controller can be tailored to operate with power supplies ranging from 18 - 48 V nominal, centre-tapped. It is convenient, but not necessary, that the motor voltage rating equal the supply voltage. The suitability of any motor-battery combination can be evaluated by multiplying both axes of the motor speed-torque curve by the ratio of (supply voltage)/(motor voltage rating).

The present design of the DCMC includes a constant frequency PWM oscillator. This is adequate for the majority of applications, but is somewhat problematic when operating with motors which have very low armature resistance (ie. < 0.75 Ohms). Because the heat sink on the DCMC has been selected in order to reduce overall dimensions, powering low armature resistance motors under heavy load can result in excessive heating of the output transistors. The design will be improved to incorporate automatic PWM frequency control so that maximum current can be delivered to low armature resistance motors while still minimizing power dissipation.

A photograph of the DC Motor Controller and a summary of its specifications are given below.

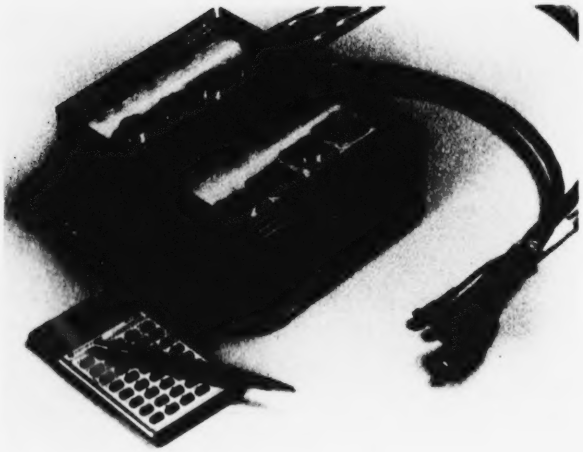

Figure 1. DC Motor Controller

Table 1. DC Motor Controller Specifications

Motor Type	permanent magnet DC motor - up to 1/6 HP (124 W)
Number of Channels	2
Input Control	maximum input amplitude: ± 1V
Joystick Potentiometers	5 - 50 k ohms
Battery Supply	18 - 48 Volts (centre tapped)
Maximum Output Current	30 Amps per channel
Physical Dimensions	8.5" x 7" x 2.5" (21.6 cm x 17.8 cm x 6.4 cm)
Weight	5 lbs (2.3 Kg)

The DCMC, like any electrical device, may suffer the occcasional spontaneous failure of an internal component. However, this is unlikely due to the reliability of modern semiconductor devices. If a failure should happen, it is unlikely a runaway motor would result since the power transistors can be activated only by complementary outputs from the control circuit. No outputs or non-complementary outputs cannot cause current flow through the motors. Inadvertant complementary outputs could only arise through the simultaneous failure of at least two integrated circuits. Thus, it is much more likely that accidental operation would be caused by a defective or poorly maintained joystick.

An unlikely failure mode, involving simultaneous short-circuiting of power transistors on opposite sides of the bridge, will result in the motor attempting to accelerate to full speed. However, by reversing power bridge direction at the joystick, the current path has been designed to bypass the motor and overload a line fuse, thus preventing further operation.

Discussion

The DCMC is expected to find application in the powered wheelchair market. Clients who already own powered wheelchairs and wish to upgrade to a new controller will find the DCMC to be smaller, quieter, more reliable and less expensive than currently available controllers. The cost of manufacturing the controller in small lots of 30 has been determined to be between $450 and $550 depending on the output power required. Larger production volumes would yield lower per unit costs than these.

Manufacturers involved in modifying electric wheelchairs may find that the DCMC can be organized to suit their needs, thus alleviating the necessity of a new design. The controller can also be implemented as a proportional control upgrade to present switch-controlled powered aids. Because its output characteristics can be tailored to specific permanent magnet motor and client requirements, the DC Motor Controller is capable of being interfaced to a wide range of electrically (DC) operated devices.

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ELECTRIC WHEELCHAIR BATTERY CHARGER PERFORMANCE

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ABSTRACT - Five popular battery chargers for 24 volt electric wheelchair batteries were tested, and it was found that two overcharged the batteries excessively on an absolute energy basis. Several battery charger performance parameters are also reported.

RÉSUMÉ - On a essayé cinq chargeurs populaires pour batteries de 24 volts installées sur des chaises roulantes électriques. On a trouvé que deux d'entre eux surchargeaient les batteries de façon excessive en termes d'énergie absolue. Plusieurs paramètres de performance d'un chargeur de batterie sont aussi examinés.

Introduction - A number of battery chargers are available on the market for recharging lead (dioxide)-lead-acid (abbreviated: lead-acid) batteries, including automotive, deep discharge wet cells, and gelled electrolyte cells. Figure 1 shows the five units tested, and Table 1 lists the manufacturer and distributor.

When considering performance in general, if the charger doesn't recharge the battery completely there will be a cumulative lack of recharge which will eventually cause the battery to exhibit poor capacity. If the charger significantly overcharges the battery the battery may be damaged due to corrosion of positive grids and excessive gassing [1, p. 303].

The battery service life depends upon the depth of discharge, environment, and charger characteristics as well as the human factor in battery maintenance. Gates [2] tests show that the cycle life of a lead-acid battery can be decreased by 1/3 by increasing the charger voltage from 2.40 volts per cell to 2.60 volts per cell. Gates [2] also show that the cycle life of the battery will increase if the battery is not discharged 100% (100% refers to a cut off voltage of 1.60 V/cell); for example, at a charger voltage of 2.45 volts per cell the cycle life at 100% depth of discharge (D.O.D.) of a Gates cell is 250 discharge/charge cycles and increases to 350 discharge/charge cycles at 80% D.O.D.

Testing - Four of the chargers tested (1, 3, 4, 5) are full wave rectified, taper current chargers while one (2) is a full wave, rectified, constant current type (with a lower constant current finish charge.) The taper current chargers take advantage to a certain extent of the Ampere-Hour Law [1, p. 244], i. e., the charging rate in amperes is kept below a value equal to the ampere-hours out of the battery. Thus, the charging current can be high at the beginning of the recharge and taper to a low value at the end of the charge. A taper current charge from a strip chart recording is shown in Figure 2 for the

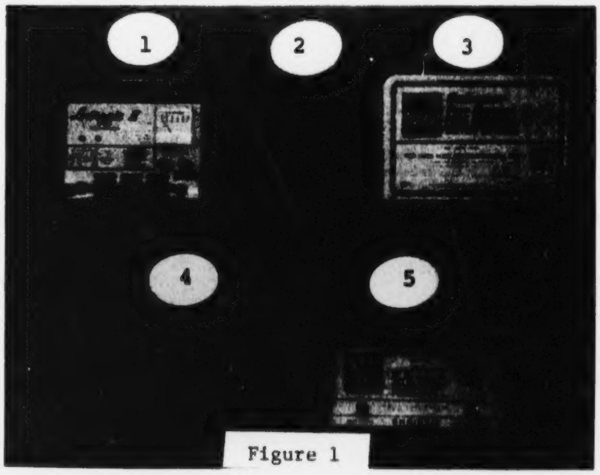

Figure 1

Figure 2

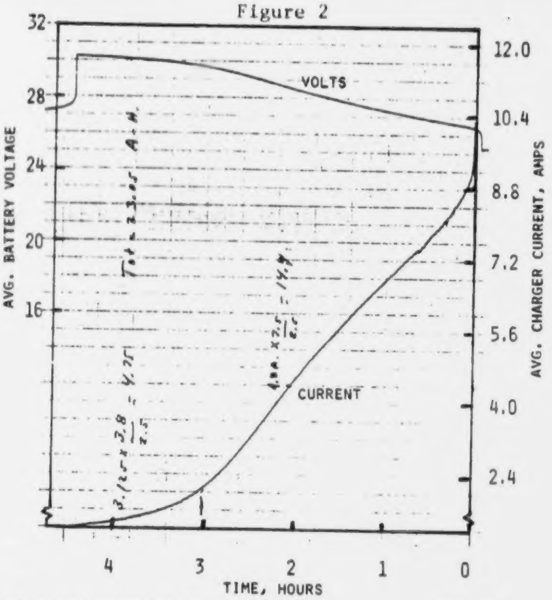

TABLE 1

	Distributor	Charger	Safety Approval
1.	Lester Electrical of Neb., Inc. 625 W. A Street Lincoln, Nebraska 68522 (402) 477-8988	Lestronic II Model 07040 115VAC-60Hz-4A 24 VDC-10A, $179.45	Submitted to Underwriters' Lab. for approval.
2.a.	Thermo Batteries Canada, Inc. 9291 Le Prado St Leonard Quebec H1P 3H1 (514) 327-3627	System Monitors Model CBC2 120 VAC-60Hz-2.5A 24 VDC-3.5A, $151/$168 +Import Fees	Canadian Standards Association
b.	Everest & Jennings Canadian, Ltd. 111 Snidercroft Road Concord, Ontario, L4K 1B6 (705) 669-2381		
3.	Schauer Mfd., Co. 4500 Alpine Avenue Cincinnati, Ohio 45242 (513) 791-3030	Four Seasons Model TB10024 120 VAC-60Hz-4.2A 25.2 VDC-10A, $113.50	Underwriters' Lab.
4.	Everest & Jennings, Inc. 3233 E. Mission Oak Blvd. Camarillo, CA 93010 (805) 987-6911	Christie Elec. Corp. Model 248E 115VAC-60Hz-3A 24VDC-8A $210	Los Angeles Dept. of Building & Safety
5.	Everest & Jennings, Inc. 3233 E. Mission Oak Blvd. Camarillo, CA 93010 (805) 987-6911 (Discontinued Model)	Christie Elec. Corp. Model 248A 115VAC-60Hz-2A 24VDC-8A $112.25 Rebuilt	Los Angeles Dept. of Building & Safety

TABLE 2

Charger	Avg. Charge Voltage Per Cell Start	Finish	Charger Efficiency	Battery Input/Output amp.-hrs.	watt-hrs.
1. Lestronic II Mod. 07040	2.17	2.47	77%	1.03	1.28
2. System Monitors Mod. CBC2	2.12	2.51	60%	1.26	1.20
3. Schauer Four Seasons (12 Hour Test) Mod. TB10024	2.10	2.44	76%	1.38	1.92
4. Christie Mod. 248E	2.14	2.56	76%	1.14	1.30
5. Christie Mod. 248A	2.10	2.53	76%	1.14	1.54

TABLE 3

Charger	Avg. Charge Voltage at 124V AC Line, Input & Power	Avg. Charge Voltage at 110VAC Line Input (After 4 Minutes) & Power	Short Circuit Test	Reverse Polarity Connection Test
1. Lestronic II Mod. 07040	28.5 VDC 200 watts	28.5 VDC 185 watts	Charger completely off. No damage - No current flow.	Big Spark. Both fuses blow. (Easily Replaceable fuses)
2. System Monitors Mod. CBC2	27.40 VDC 153.6 watts	27.40 VDC 150.6 watts	On both short circuit or reverse polarity tests, either the outside or inside (or both) fuses will blow. (Sparks often present). The inside fuse is difficult to service.	
3. Schauer Four Seasons Mod. TB10024	26.90 VDC 200 watts	26.40 VDC 40 watts	Charger completely off. No damage - No current flow.	Charger stays off without damage or current. (Best protection circuit observed).
4. Christie Mod. 248E	27.80 VDC 128 watts	26.35 VDC 41 watts	Fuse will blow only if "Start" is held for more than a couple of seconds. Nothing happens while just set on "on".	Big Spark. Fuse will blow.
5. Christie Mod. 248A	27.75 VDC 111 watts	26.80 VDC 37 watts	Same results as System Monitors charger.	

Lestronic II charger. Chargers using the Ampere-Hour Law will avoid overheating and excessive gassing of the battery while charging in the shortest time. Chargers used in the home are limited by the house current available and cannot fully take advantage of the Ampere-Hour Law. Two new 22NF size 40 ampere-hour batteries were discharged to 1.5 V/cell at 30 amps for each test. In Table 2 the initial and final average charging voltage per cell is shown. The recommended charge voltage at room temperature for long life of new lead-acid batteries is 2.45 volts per cell [2]. Since a half wave rectifier charger supplies a 50% higher peak to average voltage ratio than a full wave rectifier charger a full wave rectifier charger as used by the chargers tested is preferred [2]. The charger efficiency was measued by using an electronic wattmeter on the AC input and DC output. The loss in efficiency shows up as heat in the charger and the charger must be vented for cooling. Any accidental blocking of the air vents such as dropping a pillow on the charger will cause the temperature of the charger case to rise well above ambient temperature. U.L. or equivalent approval requires chargers to pass a test to show they cannot cause a fire if the charger is covered with a blanket or pillow.

On an ampere-hour basis the five chargers do not show excessive overcharge in Table 2. But, on an absolute watt-hour basis two chargers show excessive overcharge (3,5). For the test of the Schauer charger (3) the overcharge can be reduced at least 20% by decreasing the adjustable voltage level on the back of the charger. Overcharge is discussed by Brodsky [3] It is recommended that a lead-acid battery be overcharged only 5 to 15% and not over 40% maximum to equalize cell charge and cause the acid solution to mix by gassing [1, p. 252], and [4, p. 231, 353]. The specific value of overcharge depends upon battery temperature, age and history. Gould [4, p. 353] states, "Any charge rate is permissable that does not produce excessive gassing or cell temperature above 115°F (46°C)."

In Table 3 are given the results of tests for the effect of line voltage drop, short circuit, and reverse polarity connection. Most wheelchairs do not connect the charger directly to the battery terminals, and do have connections that cannot cause a short circuit or reverse polarity connection. The line voltage test results in Table 3 show that three of the chargers (3, 4, and 5) significantly decrease their rate of charging for a drop in line voltage to 110 VAC. Such a decrease in charging rate due to low line voltage means the battery will require a longer recharge time. Although the battery is not usually damaged by undercharging, the electric wheelchair may not operate as long as the user would like, and if the battery is continuously undercharged it will slowly "run down", as mentioned in the Introduction.

The per cell voltage of a charged battery varies with temperature so that the chargers which determine the end of charge by the cell voltage at room temperature will not charge a cold battery properly unless an ambient temperature compensating circuit is included, as claimed for the Schauer charger.

All of the chargers tested use the battery voltage rise to determine the end of charge except the Lestronic II which uses the slope of the battery voltage-time curve.

The Lestronic II takes advantage of the fact that when the battery is charged the voltage-time curve becomes horizontal. This has the added advantage that this charger can charge hot or cold batteries satisfactorily. However, the voltage-time curve of a gelled electrolyte battery is such that the Lestronics II will terminate the charge too soon. The Lestronics II operating manual specifically excludes gelled electrolyte battery application.

Conclusion - The performance of the five wheelchair battery chargers is reported and it has been found that two overcharge the battery more than is recommended. Three of the chargers have very poor low line voltage control which will require a longer charging time if the line voltage is below the charger rating. These test results indicate that wheelchair battery chargers can be improved which would lead to longer battery life and consequently better electric wheelchair performance.

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Acknowledgement

Electrical Engineering undergraduate research assistant Robert Ritter carried out several of the tests and reduced most of the data. I wish to express my appreciation to the charger manufacturers and distributors who all were very helpful with advice and equipment during the preparation of this paper.

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SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 11

PROSTHETICS AND ORTHOTICS III - LOWER LIMB/
PROTHÈSES ET ORTHÈSES III - MEMBRES INFÉRIEURS

A SYSTEM FOR MEASURING THE 3-DIMENSIONAL GAIT OF AN ABOVE-KNEE AMPUTEE WEARING A PROSTHESIS SIMULATOR

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ABSTRACT - A system developed for measuring the three-dimensional gait mechanics of an above-knee amputee is described. The amputee uses a prosthesis simulator which can emulate a variety of prostheses. Accurate data in digitized form can readily be obtained with this system.

RÉSUMÉ - On expose dans la présente communication un système mis au point pour mesurer en trois dimensions la mécanique de la démarche chez un amputé au-dessus de genoux. Celui-ci fait usage d'un simulateur qui émule un grand nombre de prothèses. On peut sans problème obtenir des données numérisées précises au moyen de ce système.

Introduction

In order to determine the design specifications and control parameters relevant to above-knee (A/K) prostheses it is essential that high quality gait measurements of amputees be made during walking trials with innovative prostheses. Obtaining gait data has been accomplished by many researchers using different measurement techniques. The purpose of this paper is to detail the assemblage of one of these techniques with a flexible prosthesis simulator system. The complete system provides the opportunity to obtain the gait biomechanics of A/K amputees using different prostheses without requiring any hardware changes in the simulator or in the measurement system. Only the program controlling the simulator is altered.

The complete system can be divided into five main sections that include:

1) hardware for measuring kinematics,
2) hardware for measuring forces,
3) software for collecting and storing data
4) hardware representing the prosthesis structure, sensors and actuator,
5) software for controlling the prosthesis.

Sections one through three represent a system developed at MIT known as TRACK (Telemetered Real-Time Acquisition of Kinematics) [1, 2, 3]. Sections four and five represent an active, person-interactive prosthesis simulator system also developed at MIT [4, 5, 6]. In this work the TRACK and simulator systems were expanded to work synchronously and, in addition, data from the simulator's transducers were merged with the data from the TRACK system[7].

Person-Interactive Prosthesis Simulator

The person-interactive prosthesis simulator is a laboratory restricted general purpose prosthesis that is controlled by a digital computer to simulate almost any prosthesis that is available or a novel controller that a prosthesis designer wishes to test. A new control scheme requires only a new computer algorithm and not a new piece of hardware. Movement of the simulator's shank about the socket is controlled by a high performance servo valve which controls the flow of 1000 psi hydraulic fluid through an actuating ram. This movement is recorded by a position potentiometer and the net torque developed by the ram and external loads about the knee is measured by a load cell and a DCDT. Other signals that are available include:

1) angular velocity of the prosthetic knee joint,
2) heel and toe contact switches,
3) the load in the shank of the prosthesis,
4) safety check signals.

All of these signals are fed back through a Digital Equipment Corporation (DEC) PDP 11/40 computer. The signals are sampled, stored and used in control algorithms to produce a comand signal to the servo valve amplifier.

Three-dimensional Kinematics and Forces

For obvious reason, measuring human motion (and the associated forces) must be done by measuring only the external motions and forces acting on the body. This information when combined with the inertial and geometric properties of the body segments of interest can be used to calculate the net force and moment vectors that must have been present to produce the recorded kinematics. This is often called the inverse dynamics problem. For an amputee, however, internal measurements are possible on the prosthesis itself. This fact is used to help simplify the measurement system used in this paper. To simplify the problem even further only the biomechanics of the amputee's prosthetic side from the hip down are measured. While this limits the ability to determine the effects of innovative prostheses on other body segments it represents only a hardware limitation and not a limitation of the methodology.

The hardware for measuring the 3-dimensional kinematics is a Selspot I system (Selcom AB, Goteborg, Sweden). The system has a pair of cameras with lateral-photo-effect diodes (detector plates) at their focal planes. These detectors are sensitive to infra-red light, and (with the aid of some additional electronic equipment) produce a digitized signal representing the "x,y" location of the centroid of the infra-red light incident on the detector plates surfaces. With two cameras producing four pieces of information (x,y location on each detector plate) the three-dimensional location of the origin of the infra-red light can be determined. The infra-red light spot on the detector plates comes from an infra-red light emitting diode (LED). If at least 3 LEDs are mounted on a rigid surface or surfaces such that the LEDs are not colinear then the three-dimensional position and rotation of a coordinate system attached to the LED array can be determined.

For the measurement task outlined in this paper, a planar array of 14 LEDs was securely fastened to the shank of the prosthesis. In addition, a lightweight shroud was placed between the array and the prosthesis to prevent any infra-red light from reflecting off the surfaces of the prosthesis.

A large planar array containing 14 LEDs (instead of the required minimum of three) was used to improve the accuracy and reliability of the system. The accuracy is improved because calculating the rotation matrix can be done more accurately if the LEDs are far apart with respect to the positional resolution of the Selspot system. The reliability is improved due to the cross checking the TRACK system provides of the LED spacing on the array.

The inverse dynamics model requires the kinematics of all the independent mass segments. This means that the kinematics of the shank and thigh must be measured. A second LED array could have been placed on the socket but the prosthesis has a position potentiometer measuring knee angle as explained previously. Since the socket and shank are geometrically constrained to rotate in the same plane, the complete three-dimensional kinematics can be recorded using one LED array on the shank and the position potentiometer at the knee. It should be noted that with this method of measuring the kinematics any motion that might exist between the hip and the socket will not be measured.

The hardware used to measure the foot/floor interaction forces required for the inverse dynamics model is a Kistler 9281A, multi-component force sensing platform (forceplate) (Kistler Instrument AG Winterthur, Switzerland). The forceplate is mounted flush with the surrounding floor surface [5] approximately 25 feet from the start of the 60 foot walkway. The forceplate measures: force in three orthogonal directions, position of the net center of force on the platform's surface, and the torque about an axis perpendicular to the surface of the forceplate.

All of the data produced by the Selspot and forceplate systems are recorded by a DEC PDP 11/60 computer [2]. In addition, a signal initiated by the experimenter is sent to the 11/60 and 11/40 computers to begin synchronously the data storage windows (typically several seconds in length). The data storage of the simulator system's sensors proceeds without interfering with that computer's primary task of controlling the prosthesis simulator.

Preliminary tests indicate that the complete system still meets the previously reported performance specifications for the TRACK system [2]. These are a positional accuracy of ±1 mm and rotational accuracy of ±1.2 degrees. The force plate accuracy is given by the manufacturer as .3% over the load range. The accuracy of the calculated joint torques and forces will be, of course, less than the above specifications due to the noise amplification inherent in the differentiating process.

In summary the system presented provides an accurate, high speed method for obtaining the gait biomechanics of an A/K amputee using a single prosthesis which can be controlled to simulate a large variety of prostheses. This system is currently being used to obtain gait data of amputee s using a variety of stance phase knee controllers.

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OTTAWA EXPERIENCE WITH HIP DISARTICULATION PROSTHESES

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ABSTRACT - The results of a survey on hip disarticulation amputations and prosthetic needs are being used to develop experimental designs with a view to providing more comfortable, lighter weight, and cosmetically attractive prostheses. Eight patients have been fitted to date.

RÉSUMÉ - Les résultats d'une étude des désarticulations de la hanche et des besoins en prothèses servent à mettre au point des modèles expérimentaux dans le but de fournir des prothèses plus confortables, plus légères et plus esthétiques. Huit patients ont reçu ces prothèses jusqu'ici.

By far the greatest rejection rate among prosthesis users in the group of lower extremity amputees is that of the high level amputee i.e. very short above knee, hip disarticulation and complete or incomplete hemipelvectomies (or trans pelvis amputations). In order to assess the state of the art in these categories, a study was initiated in 1979 among clients who had failed to gain satisfaction from their prostheses and had ultimately resorted to ambulation on crutches rather than be restricted by ungainly awkward artificial limbs.

Numerous letters written to well-respected prosthetists, physicians and rehabilitation engineers around the world solicited opinions on the apparent lack of success in fitting these clients. After compiling the data from these sources, no definitive protocol or fitting technique emerged to be used as a base for further development. As well, direct patient feedback on a number of prosthetic designs with readily available combinations of prosthetic joints and socket materials showed no apparent increase (or decrease) in prosthetic use by the amputees.

In 1982, several amputees were again fitted with slightly different combinations of components and sockets. Through the use of questionnaires, speaking to other professionals in the field and client feedback, a pattern began to develop which identified the areas of greatest concern to the patient. Some of these were as follows - socket discomfort, mobility, weight of prosthesis, insecurity, and energy expenditure.

METHODOLOGY

Utilizing the gait laboratory of the Royal Ottawa Regional Rehabilitation Centre, angle-time diagrams from hip, knee and ankle joints were recorded by electrogoniometers; graphs were plotted by a PDP11 computer to focus on such concerns as mobility, speed and energy expenditure. The same was done for step length, force-displacement and weight distribution as recorded by a force-platform. A split image video-recording projected the patient simultaneously from a lateral aspect as well as from an anterior or posterior view. This latter feature was extremely helpful in analyzing the various stages of the gait-cycle as the recording could be re-played frame by frame.

Furthermore, the amputee found viewing the video tapes helpful in understanding why he/she walked in a certain fashion. Once taught how to correct these gait faults, the individual did so quite readily. By cross examining both video recordings, the prosthetist was able to align the prosthesis more accurately.

The amount of energy expenditure required to walk at a standard walking rate while wearing different prostheses can be measured by an oxygen consumption analyser (1). By measuring energy expenditure, it has been observed which type of prosthesis requires the least oxygen consumption. This observation should affect future prosthetic modifications.

AREAS OF CONCERN

1. Socket Discomfort

The location of greatest pressure is usually on the ischial tuberosity where most of the weight is borne, both in walking and sitting. Most conventional sockets with rigid or semirigid polyester laminations are only slightly padded with felt, pelite or leather in this area. In some cases, weight was borne in the smyphysis pubis area which resulted in an abducted gait and awkward sitting positions.

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(1) Not available at RORRC at present time.

Patients complained of skin breakdown, heat rashes and general discomfort. They also complained of problems from the proximal socket rim which tended to dig into the lower ribs during sitting and bending, usually leaving large bruises.

Some of these complaints were overcome by using rubberized sockets fabricated from various RTV silicone rubbers or IPOCON (1). Various custom socket changes to create different weight bearing areas, ie. below the iliac crest, proved satisfactory in several cases. Further studies need to be done to fully assess the advantages and disadvantages of the use of these materials.

2. Mobility

Lack of mobility can lead to painful and embarrassing situations. Most patients complained of the necessity of thoroughly planning ahead, once away from their familiar home or working environment. Within the area of mobility, two concerns arise for the amputee - velocity and manoeuverability.

Most amputees are quite adept crutch walkers and can cover a larger distance in a shorter period of time on crutches than walking with their prostheses. In a number of cases, to encourage prosthesis use, special hip and knee extension assists were used to increase the velocity of walking. However, new but undesirable elements were brought into play by these adaptations. These features were eventually rejected by the patients.

Manoeuverability is a daily problem encountered by hip disarticulation patients on a large scale. Some of these problems lie in the type of terrain covered, lack of space to manoeuver and the motion of sitting and standing. Again, further research in this area is of utmost importance to 'win over' the crutch walker and encourage him to give wearing the prosthesis another try.

3. Weight of Prosthesis

The average weight of the prosthesis varies from 4 to 9 kilograms (depending on the additional extras in the prosthesis) which is generally deemed acceptable. The use of torque absorbers, 4-bar linkage hip and knee joints, and multi-axial feet all added significantly to the overall weight.

The selection of lighter materials for the hardware as well as the socket is of great importance. With the current technology at our disposal, this does not seem an unreasonable goal to achieve.

4. Insecurity

The fear of falling unexpectedly is a great concern to most hip disarticulation amputees. Despite the use of mechanically sophisticated hip and knee joints, using self locking and breaking mechanisms, extension assists propelled by springs, pneumatic or hydraulic cylinders, insecurity still remains with the patient. Heel elevation also created anxiety for the patient. The use of more than one prosthetic foot with various heel heights and/or the use of a T-handled Allen key, can alleviate this problem to a certain extent.

Various myo-sites to explore the possiblity of voluntary joint control in the hip and knee joints are now being investigated by various researchers. Presently, no motor-drive units or other safety mechanisms are available.

5. Cosmesis

Cosmesis plays just as important a role as the mechanics of the prosthesis. Most endoskeletal prostheses offer a much better cosmetic appearance than exoskeletal designs. However, there are still some drawbacks with both designs. The socket area enveloping the entire pelvis adds significantly to the hip and waist circumference. The distortion of the hip area from standing to sitting should also be considered in redesigning the total shape. The appearance of the sitting position was also improved by levelling the pelvis through the use of two new hip joints.(2)

'Cosmetic' noise produced by some joints as well as foam covers are presently under investigation.

SUMMARY

These independent findings form a basis for further investigation into priorities for the redesign of the hip disarticulation prosthesis in which the wearing of the limb will be optimized and normalized.

NOTE: Further communication or correspondence with the author would be appreciated.

(1) IPOCON - product of IPOS, distributed by W. H. Hood Co., Vittoria, Ont.

(2) Research with Otto Bock 7E7 and 3R21 at RORRC.

DYNAMIC FUNCTION OF THE SACH HEEL

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ABSTRACT - Parallel linear mechanical elements (spring and dashpot) are utilized to model the dynamic load characteristics of the SACH heel. Experimental data and gait data are used to define the parameters of the model to approximate the behavior of the SACH heel.

RÉSUMÉ - Des éléments mécaniques linéaires parallèles (ressort et amortisseur) sont utilisés pour simuler les caractéristiques de charge dynamique du talon SACH. Les données expérimentales et les données relatives à la démarche sont utilisées pour définir les paramètres du modèle de manière à représenter le comportement du talon SACH.

INTRODUCTION

Heel strike transients in the tibia of greater than 5 g's have been noted while walking on a hard floor with hard leather shoes (1, 2). Those authors reported that the use of an energy absorbing medium in the shoes significantly reduced the skeletal transients. Mizrahi and Suzak (3) reported accelerometer studies at the greater trochanter for people who had dropped from heights of 5 to 7 centimeters onto one leg. Accelerations at the greater trochanter as high as 4 1/2 g were measured, pointing out the high loads which can be transmitted by impact loading. This study is a preliminary report aimed at characterizing the impact properties of the SACH heel with the intent of optimizing its qualities in terms of damping transients transmitted to the amputee stump. In this study, linear mechanical elements are utilized as a model to describe dynamic characteristics of the SACH heel and the results of this modelling are compared to amputee heel compression data at heel strike.

MATERIALS AND METHODS

The model is a mechanical system with massless elements consisting of a spring and viscous dashpot placed in parallel. This system is described by the second order linear differential equation:

$$m \ddot{x} + c \dot{x} + k x = f(t)$$

where f(t) is the external force applied to the system as a function of time. The forcing function f(t) was chosen to be a step function of magnitude corresponding to the vector sum of the measured vertical and fore-aft force-plate forces. The variables x, $\dot{x}$ and $\ddot{x}$ are the displacement, velocity and acceleration of the heel and m, c and k are the mass of the system, damping coefficient and spring constant of the heel. The equation is solved for x(t) by use of a Laplace transformation with a given initial conditions that $\dot{x}(0) = 0$, $x(0)=0$ at $t = 0$. This type of solution is useful in dealing with pulsing or switching problems where there is a discontinuity in the time function. Certain assumptions are made in this analysis. Only the problem of linear cushioning of the SACH heel including vertical and fore aft forces is addressed, and medial lateral and torsional forces on the heel are neglected. The mass is assumed to be the mass of the subject and to act in a rigid manner.

The parameters necessary for describing the model were obtained from experimental data and patient gait data. The spring constant k was chosen from static testing data of the SACH foot (4). The gait data was obtained from a study conducted by Golbranson and Wirta at Children's Hospital in San Diego on below-knee amputees. Sixteen mm. movie film and force plate data obtained through the courtesy of those investigators and M.P. Wyatt was used to make measurements for this preliminary report. These amputees were characterized by Golbranson and Wirta as being among their "best" walkers. The data used in this study is shown in Table 1. The maximum heel compression was obtained by measuring the displacement of the SACH heel (exclusive of shoe compression) in relation to the remainder of the BK prosthesis. The maximum force is the vector sum of the fore aft shear and the vertical force component. The Vanguard Motion analyzer was used to determine the SACH heel compression as a function of time. The maximum displacement was used in the model for each subject. Using these values the equations of motion were used to derive a value for c, the damping coefficient. Choice of a damping coefficient permitted calculation of the behavior of the SACH heel at heel strike.

RESULTS

The variation of heel compression with time for the chosen value of the damping constant c is shown compared to the two displacement-time curves obtained directly from gait data (Figs. 1 and 2). The calculated damping constant was found to be in the underdamped condition, in which a damped oscillation occurs. The derived value of c was equal to 2000 N-sec/m. for Subject 1 and 1350 N-sec/m for Subject 2. Changes of 100 N.sec/m in the damping constant resulted in maximum changes of approximately 0.1 cm in displacement of the heel. The use of a step function for a forcing function allows correlation of static testing data with the dynamic model.

DISCUSSION

Mathematical models of a SACH heel which contains a viscoelastic material offer the benefit of demonstrating the effect of design changes by permitting the parameters of the model to be changed rather than by building and testing prototypes. Use of data from the model provides a good approximation very rapidly as to how a physical SACH foot with a corresponding heel will perform. One can then optimize design parameters so that only worthwhile prototypes are constructed. This model may be very useful in optimizing the function of the SACH heel.

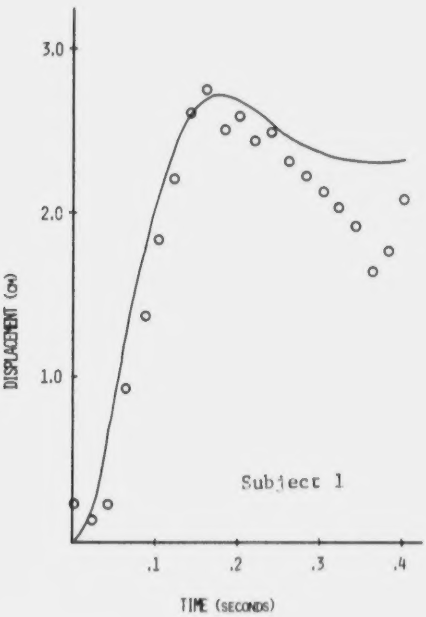

Figure 1

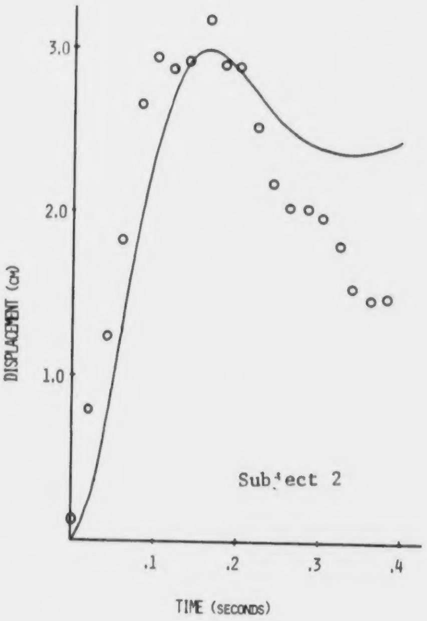

Figure 2

Table I data on two BK amputees utilized in this model.

	Subject 1	Subject 2
Mass (kg)	90.9	70.5
Maximum Force (N)	952	807
Maximum Heel Compression (cm)	2.72	3.00
Spring Constant (N/M)	40000	32500

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IMPROVEMENT OF THE AIR-CUSHION SOCKET FOR BELOW-KNEE AMPUTEES

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ABSTRACT - The air-cushion socket, when properly fabricated, is a highly successful socket for below-knee amputees. However, inconsistent results, due in part to a complicated fabrication procedure, have prevented the more widespread use of this socket. Improvements in the fabrication technique are described which overcome these problems.

RÉSUMÉ - Le monchon à coussin d'air, lorsqu'il est fabriqué avec soin, est un manchon très efficace pour les personnes ayant été amputées sous le genou. Cependant, le manque d'uniformité des résultats, partiellement attribuable à la complexité du processus de fabrication, a empêché la diffusion plus large de ce manchon. Les auteurs décrivent des améliorations de la technique de fabrication qui surmontent ces difficultés.

INTRODUCTION

Despite early success, the air cushion socket has enjoyed only limited popularity and the principle upon which it is based has been criticized. The major objections to the original design are the lack of adjustability of fit and the complicated fabrication technique which did not always yield the desired leak proof air space.

The successful use of the socket depends on the determination of the proper volume of enclosed air space for each individual stump and maintenance of the integrity of this enclosed air space. The key word is enclosed, for if air leaks from the socket, the beneficial effects of the air cushion are lost and the stump will ride in an elastic sling instead of on a cushion of air.

The union of the elastic sleeve to the plastic socket is the main site of air leakage because there is no chemical bonding between the silicone rubber elastomer and the polyester resin at the proximal border of the elastic sleeve. Air leakage becomes worse with constant use of the socket because the elastomer/polyester resin union breaks down.

BACKGROUND

The air cushion socket (Fig. 1), developed in the mid-sixties by Wilson et al (1), was a response to the need for a below-knee socket which would eliminate edema problems and abrasions that result from the rubbing of skin against the internal surface of the socket.

This socket incorporates an internal R.T.V. (room temperature vulcanizing) silicone elastic sleeve which is attached proximally to the inside of an external rigid polyester shell. The elastic sleeve encloses the distal end of the stump below the level of the tibial tubercle. Support is provided distally through tension on the elastic sleeve and through variable pressure provided by compression of a sealed air volume, distal to the elastic sleeve.

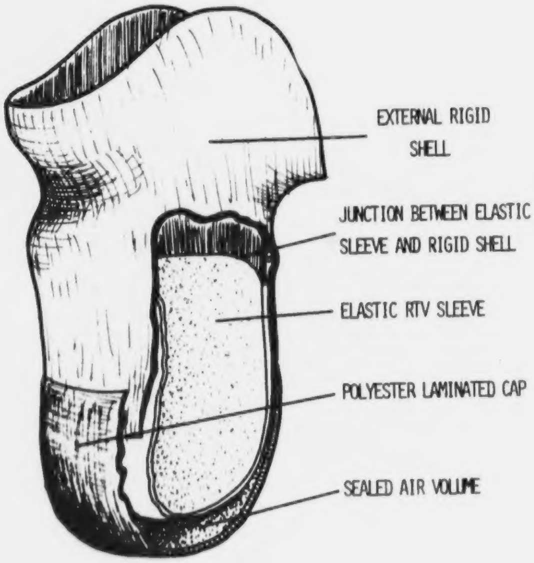

FIGURE 1.

The elasticity of the air cushion sleeve reduces the tendency for the skin to stretch over the distal tibia and/or fibula, and eliminates abrasions (1). The compressed air volume provides increased but comfortable pressure on the distal end of the stump so that pressures on the patellar tendon and on the popliteal area may be reduced. This higher pressure on the distal as compared with the proximal portion of the stump minimizes the risk of development of edema.

METHODS AND MATERIALS

The problem of lack of adjustabilty of the socket has been solved by the use of an open ended, soft insert liner (Fig. 2). This allows the prosthetist to modify the fit of the socket in response to changes in the amputee's stump.

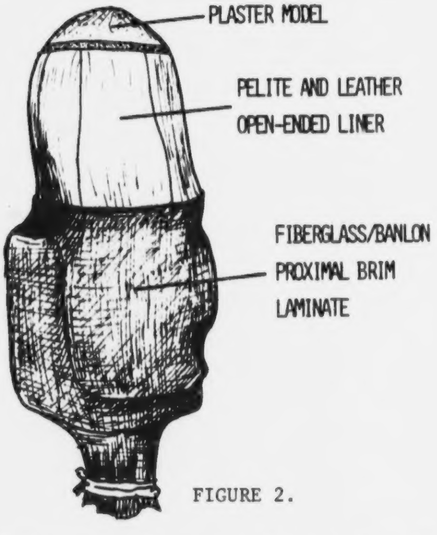
PLASTER MODEL
PELITE AND LEATHER OPEN-ENDED LINER
FIBERGLASS/BANLON PROXIMAL BRIM LAMINATE

FIGURE 2.

Changes in the socket fabrication technique consists of the lamination of a thin polyester resin brim which encapsulates the proximal portion of the plaster model to a point 3/8 in. (10 mm) distal to the level of the tibial tubercle (Fig. 2). The elastic sleeve is then laminated over the model to a level 3/8 in. (10 mm) proximal to the distal edge of the polyester brim. A 1/16 in. (2 mm) diameter cotton cord loop is placed over the outer layer of the banlon at the level of the tibial tubercle, prior to pulling on the outer PVA bag (Fig. 3). The cotton cord loop has a dual purpose. It serves as a collection point for the R.T.V. rubber (thus forming a slight bulge) and as a retainer, preventing the R.T.V. from bleeding into the fabric beyond the desired point of lamination. The fabrication procedure now continues as previously outlined by Wilson et al (1). The R.T.V. bulge at the proximal border of the elastic sleeve is thus sandwiched between two polyester resin laminates (the outer socket and the inner proximal brim) and forms an airtight barrier (Fig. 4).

DISCUSSION

This new technique involves an additional step but requires no additional fabrication time over the previous technique. This is because the lamination of the elastic sleeve has been greatly simplified. It is no longer necessary to use rubber wedges (1) to prevent the silicone rubber from spreading beyond the intended proximal border of the elastic sleeve. This technique was time consuming, frustrating and gave inconsistent results, particularly in the hands of the inexperienced.

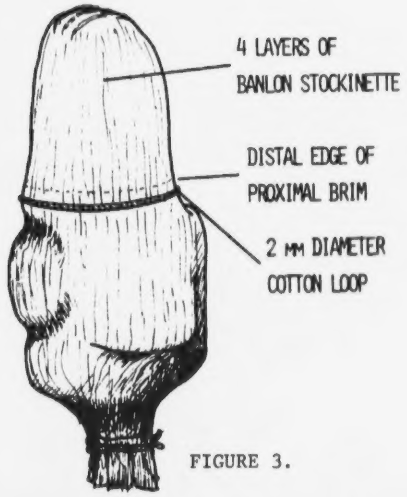
4 LAYERS OF BANLON STOCKINETTE
DISTAL EDGE OF PROXIMAL BRIM
2 MM DIAMETER COTTON LOOP

FIGURE 3.

The main advantage of the new technique is that the proximal bulge of the elastic sleeve is locked between two layers of polyester resin laminate (Fig. 4). When the elastic sleeve is stretched during weight bearing, the proximal bulge is wedged down in the narrow gap formed by the laminated socket and the distal edge of the proximal brim. Thus, a leak-tight seal is provided without need for chemical bonding between the silicone rubber/polyester laminate junction line.

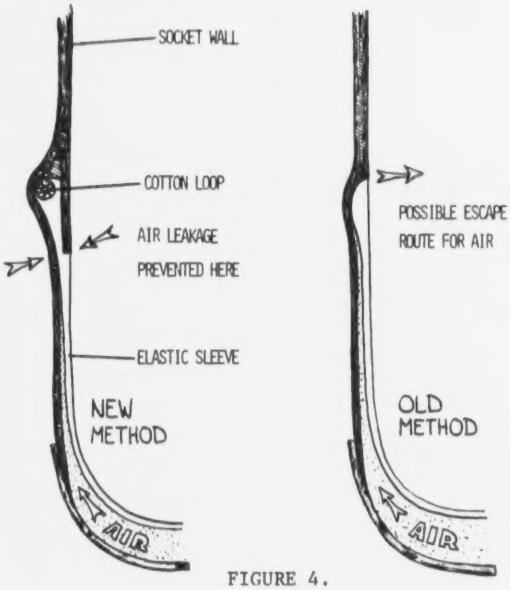
SOCKET WALL
COTTON LOOP
AIR LEAKAGE PREVENTED HERE
ELASTIC SLEEVE
NEW METHOD
AIR
POSSIBLE ESCAPE ROUTE FOR AIR
OLD METHOD
AIR

FIGURE 4.

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LIGHTWEIGHT THREE-COMPONENT BELOW-KNEE PROSTHESIS

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ABSTRACT - The design, development and application of the Lightweight Three-Component Below-Knee Prosthesis which will combine the advantages of light weight construction, prefabrication of shank and foot components, a more fool-proof method of alignment. and improved foot function and gait performance, is described.

RÉSUMÉ - Les auteurs décrivent la conception, la mise au point et l'application de la prothèse sous le genou à trois éléments qui offrira les avantages de la légèreté, la possibilité de préfabriquer le fût et le pied, une plus grande précision d'alignement, un meilleur fonctionnement du pied et une amélioration de la démarche.

INTRODUCTION

In a recent survey conducted by the R.R.&D program at this hospital (1), alignment, weight and foot functions were all determined to be significant problem areas for below-knee amputees. The light weight Three-Component Prosthesis is an attempt to address each of these problems with a system that offers consistent results with an approach that is faster, less error-prone and allows a savings in material and labor costs. There have been other light weight exoskeletal prosthesis (2, 3) that are similar to the Three-Component design. None of these systems incorporate the use of prefabricated shanks which allow faster fabrication of prosthesis and substantially reduced labor.

METHODS AND MATERIALS

The prosthesis, illustrated in fig. 1, consists of three components: the socket, the shank/keel, and the foot. Note that the shank and the keel portion of the foot are fabricated in one piece. The present system offers a choice of six shank sizes (six rights and six lefts) with two to three foot sizes per shank. The shank dimensions were determined from anthropometric survey data (4) and from practical experience in fabricating prototype prostheses for patients. The proposed range of sizes is expected to fit at least 85-90% of the amputee population. These dimensions will be used in the construction of the standard molds, which after testing will become prototypes for prefabrication molds. The present prototype shanks are fabricated over plaster of paris models using polyester resin with a nylon stockinette and fiberglass cloth matrix.

During assembly, the socket, which is custom-made for the individual amputee, is inserted inside the appropriate shank. The two are joined at the level of the tibial tubercle. The exoskeletal shank is sufficiently flexible at the proximal brim that minor differences in socket circumference or shape can be easily accommodated. Adjustments in length are facilitated by trimming the proximal aspect of the shank as needed. Once the length and alignment have been established, the socket is permanently attached to the shank using a mixture of Solka Floc and polyester resin. The foot component, consisting of the heel, toe and sole portions of the foot, is fashioned separately and then glued and screwed to the bottom of the flat based keel.

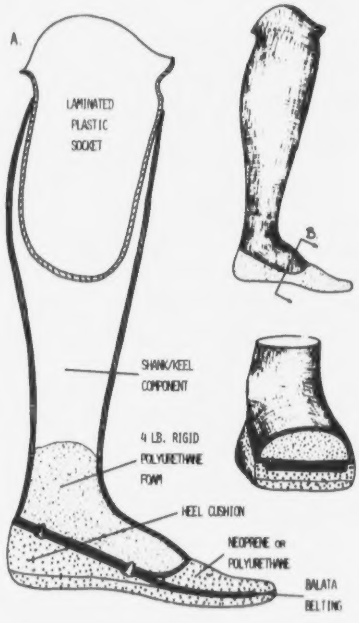

FIGURE 1. The Three-Component System.

Alignment of the prosthesis is accomplished at the socket/shank interface. The socket can be shifted inside the shank component in order to provide any necessary alignment adjustments, such as: abduction, adduction, flexion/extension placement of the socket, inset and outset of the foot, and axial rotation for toe-out angle. Because these adjustments are made at the level of the tibial tubercle, very small changes in the socket position will allow the alignment of the foot to remain in it's original orientation. In other words, the prealignment position of the foot is maintained and the amputee stump alignment is done by adjustment of the socket at the MTP level. This is in contrast to the use of an alignment jig where the point of alignment is at the distal aspect of the socket. Thus, changes in flexion/extension or abduction/adduction require a second compensating adjustment in foot position. No alignment jig is necessary with the Three Component system, as alignment is carried out during actual walking trials by adjustment of the socket in the shank with temporary fixation. This streamlined method of alignment saves time and is expected to produce fewer alignment errors.

DISCUSSION

Total time for fabrication, alignment, and finishing is 30 to 50% less as compared to standard weight type exoskeletal prosthesis. The weight of the Three-Component limb is approximately 2.5 pounds, a significant reduction in weight compared to standard limbs.

The development of a successful light weight below-knee prosthesis would be of significant value to the below-knee amputee population. Elderly amputees would especially benefit from a lighter weight prosthesis.

Prosthestists will benefit by having available to them a modular prosthesis with prefabricated components that takes less time and effort to fabricate and satisfactorily align.

RESULTS

Based on initial results, the Three-Component Prosthesis demonstrates the following advantages:

1. Light weight.
2. One-third to one-half savings in fabrication time.
3. Easily aligned.
4. Can be adapted through the use of standarized shank and foot molds to a prefabricated system.

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ROCHESTER PARAPODIUM

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ABSTRACT - A redesigned parapodium has increased the range of activities of the young paraplegic child. This will be demonstrated with a short informative film "All By Myself" that was prepared professionally for the Birth Defects Center of the University of Rochester.

RÉSUMÉ - Un parapodium repensé a élargi la gamme des activités des jeunes paraplégiques. Il fera l'objet d'une démonstration appuyée d'un court métrage d'information intitulé "All By Myself" qui a été préparé de façon professionnelle pour le Birth Defects Center de l'Université de Rochester.

The Biomechanics Team at the University of Rochester Medical Center has been developing and testing design modifications to the Toronto parapodium since 1975. Early in 1983, these design modifications had stabilized and prototypes of the new design were offered to medical centers and orthopedic laboratories in the United States and Canada. The Rochester parapodium has now been fitted to over 80 young children of ages 17 months to 14 years. Most of these children have flaccid paralysis due to Spina Bifida or spinal injury ranging from L5 to T12.

The Rochester parapodium differs from the Toronto design in the hip and knee hinge and locking mechanisms. The hip joints unlock together with a single lever release and lock automatically on extension. Independent of the hip joints, the knee joints also unlock with a second single lever release and lock automatically on extension with the aid of an extension assist bar. This separated locking and unlocking action has simplified many everyday activities for the paraplegic child. With increased control over his joints and with one hand free for balance control, the child can become independent in sitting and standing from a chair with arms. He can also bend over to pick up objects from the floor with hips flexed and knees locked. These are important functions for a preschooler exploring his surroundings and participating in peer group activities.

Previously children wearing the parapodium had to get up from a prone position on the floor by pulling to standing with fully extended knee and hip joints. Now a child can use jackknife-like movements to stand. These movements appear to require much less energy and open the activity to children with higher levels of paralysis.

The lateral supports have also been redesigned for the Rochester parapodium, using bar stock instead of tubular sections. These flat lateral supports facilitate rolling, a very important movement for a child who is independent in dressing and changing positions. The new side bar design, a more rigid construction, also improves the child's momentum during swivel walking. With polypropalene added to the bottom of the base, many children can learn to swivel walk at functional speeds, with hands free.

In total, the activities now possible with the new design allow the paraplegic child to function at home and in school with relatively little need for adult supervision or assistance.

A short film will be shown to demonstrate the potential for a paraplegic child trained to use the Rochester parapodium. This film "All By Myself" can be rented or purchased, for example, by agencies working with Spina Bifida children.

Partial support for this work has been provided by the J. M. McDonald Foundation, Cortland, NY.

A COMPLIANT INTERFACE FOR PRESS-FIT TOTAL KNEE REPLACEMENT

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Several particular designs of cemented condylar knee replacements have shown a high success rate in up to 9 year follow-ups in the elderly patient. However, there is a need for a more durable interface for the younger, more active patient. Prior to the introduction of cement, press-fit metallic hemiarthroplasties showed remarkable durability in a high proportion of cases. By optimizing the press-fit concept, using specially shaped bone surfaces and implants of suitable geometry, it may be possible to design total knees in the same way. Further enhancement may be possible using a compliant interface to spread stresses and isolate micromovements. Laboratory and animal studies are reported.

1 INTRODUCTION

The earliest knee replacements were metallic replacements of the femoral or tibial condylar surfaces, or metallic hinges. The condylar type were interfaced directly on to trabecular bone as in the McKeever tibial plateau[1] or the MGH femoral condyles.[2] "Fixation" was durable and not a reason for failure. In the McKeever's, a sclerotic line developed beneath the component.

Most of the knees used today are of the condylar replacement type, replacing femoral and tibial surfaces, attached to the bone using acrylic cement. The bones are generally prepared by making "square cuts", while the alignments are achieved using special guides. Devices used in the early 1970's showed loosening failures, due to poor cement technique, incorrect component alignment, patella impingement, components too small a surface area, plastic deformation, and excessive femoral-tibial constraint. However, some designs avoided serious problems, providing follow-ups of almost ten years. For example, the Total Condylar,[3],[4] followed for 5-9 years, had only two percent failure for loosening. There were 41% with radiolucency on the horizontal surface of the tibial plateau, but of these 32% showed the radiolucency at one year. There was minimal progressive indications. Similar figures were provided in another 5-9 year series of the Intramedullary Adjustable.[5] In our laboratory we studied radiolucency on 45 cases of Duopatella replacements, using radiographs immediately postop and after a minimum of 2 years follow-up.[6] There was a strong inverse relationship between the presence and thickness of a radiolucent line, and postoperative cement penetration. In a recent follow-up of Kinematic Condylar knees,[7] radiolucency occurred in only 17% of the cases, due to: poor initial cement penetration due to inadequate pressurization,[8] dense bone, or retained subchondral bone, and misalignment, usually undercorrected varus.

More recently, non-cemented porous ingrowth knees have been used clinically,[9] the results showing evidence of ingrowth in some parts of the interface, but lines of radiolucency in other areas. Uncemented implants with adjunct fixation such as blades[10] or press-fit plastic pegs[11] have been used. In the former, sclerotic lines usually developed at the interface, while in the latter, this occurred in some, with no changes in others.

Because the clinical results with cement are unlikely to be improved upon significantly by other methods, the impetus to develop alternative fixation methods must be:

(a) that cementing is probably unsuitable for the younger more active individuals.
(b) that the method would simplify and shorten the operative time.
(c) that the cost of the components and material would be reduced.

A condition of the method must be that the fixation is at least as durable as with cement.

HYPOTHESIS. In a normal joint, the bone experiences various patterns of stress to which the bone is adapted. As arthritis develops, the stress patterns change, the bone alters its mechanical properties and shape, further altering the stress distribution, and so on. If a correctly aligned prosthesis is inserted, the forces at the joint may be restored to close to normal. For the bone to successfully readapt in the long term, the overall stress distribution at the implant-bone interfaces must be reasonably close to a normal state. However, a further condition is that the local stresses in the trabecular bone close to the interface surface must also be reasonably normal. The purpose of our study was to investigate a possible interface which would satisfy the conditions of stress distributions at the macro and micro levels.

2 MATERIALS & METHODS

2.1 Pressure Distribution

Pressure sensitive film was used (Fuji-film) to provide a color density map proportional to local contact pressure. To obtain a flexible and compliant interface, a double-sided dacron velour was obtained. The velour was 1mm thick undeformed, and 0.3mm fully compressed, made from 15µm diameter fibers. Six fresh tibias were fixed in a base and a level cut was made just below the subchondral bone on a band saw. The trabeculae were thoroughly cleaned. Low Pressure Fujifilm was placed on the surface, a layer of velour was placed on top, a flat granite block was placed on top of the velour, and an axial load was applied in a test rig (Fig. 1). A second pressure pattern was obtained without the velour. Pressure patterns were sequentially obtained at 1000, 2000 and 3000 Newtons, with and without the velour. Liquidy Simplex P cement was pressed 2-3 mm into the bone surface, and the granite block was loaded at 1000N until hardening. After removing the granite block, pressure patterns were obtained between the block and the flat cement layer, at 1000, 2000 and 3000N as before. Five millimeters was then resected from the tibia on the band saw and a further set of pressure patterns obtained.

The pressure patterns were photographed and input to a computerized optical imaging system. The image was divided into 100x100 pixels and light intensity was measured at each pixel. To determine the surface area of bone involved in load-bearing, the number of pixels recording pressure value above a low threshold level were counted.

2.2 In Vivo Experiments

Two models were developed for the upper tibia of the sheep. The first model was to make an osteotomy parallel to the upper surface and 5mm below it and to insert a velour implant. The implant consisted of a double layer of double sided velour stuck together with a thin layer of methylmethacrylate cement, to avoid tissue growing completely through. The second model was to remove the upper tibia and replace it with an anatomically shaped cobalt-chrome implant, with a layer of double-sided velour sandwiched between it and the bone (Fig. 2). Four sheep were operated bilaterally, two sheep with model 1 and two with model 2. The operations on each sheep were at two month intervals to allow recovery from the first operation. The animals ambulated reasonably well after a few days and appeared to apply normal weight-bearing after 2-4 weeks. They were sacrificed at follow-up times of 2 months and 4 months. The joints were recovered, the soft tissue cleaned and the metal implants removed. The Dacron layer was in all cases attached to the bone with the tissue in some areas having grown through the upper surface of the velour. Sections perpendicular to the surface were made for calcified and undecalcified histology, microradiography and scanning electron microscopy.

3.0 RESULTS

3.1 Pressure Distribution.

The pressure patterns consisted of a multitude of red spots of variable color intensity and size, indicating load tranmission to trabeculae. There was a more diffuse coloration with cement. The number of contacts and the intensity at each contact increased with load. The pressure patterns between the granite block and the bone at 3000N showed trabecular contacts over discrete areas, still a small proportion of the total area. These pressure areas were usually concentrated on the medial and lateral sides, as well as the periphery. The velour patterns were similar, but the load was spread over a larger number of trabeculae. With cement, the areas were also similar, but showed a gradation of pressure rather than loading through discrete trabeculae. A typical set of pressure patterns after optical imaging is shown (Fig. 3). The numbers of contacts (pixels) for the different interfaces were:

	Number of Contacts		
	Mean	S.D.	N
Rigid interface	1645	543	11
Velour interface	2500	1038	11
Cement interface	1399	419	9

Comparative ratios of contacts and t-test significances were:

	Mean	S.D.	Signif.
Velour/Rigid	1.59	0.63	$.02<P<.05$
Cement/Rigid	1.11	0.51	$P>0.5$
Velour/Cement	2.03	1.20	$0.1<P<0.5$

One test showed that a second velour layer increased the contacts by 34% over 1 layer.

3.2 In Vivo Experiments

After two months (Fig. 4) the velour became about 50% engulfed with fibrous tissue, the tissue being most dense at the bone side of the velour and more loosely structured away from the bone. In some of the regions close to the trabecular bone, the fibrous tissue appeared to be differentiating into woven bone, but there was no evidence of dense trabecular bone however. The cellularity of the fibrous tissue was normal. The original trabecular bone just below the resection level was not sclerotic, while foreign body giant cells, bone marrow fibrosis and osteoclastic activity were not seen.

After four months (Fig. 5) tissue had invaded virtually all of the spaces in the velour. Averaging all of the sections studied, the tissue consisted of 60-70% of fibrous tissue, the remainder being mature or immature bone. The vascularity in the fibrous tissue had increased compared with that at 2 months, but the vascularity in the trabecular bone beneath the velour was still normal. Considerable woven bone was seen within the lower half of the velour in most of the sections, while in some sections, trabeculae which were connected to the underlying trabeculae had invaded the velour. In these instances, the velour fibers were completely encased within the bone. As with the two month specimens, there was a complete absence of osteoclastic activity, foreign body giant cells and bone marrow fibrosis. Studies at high magnification showed that when the velour fibers were encased within fibrous or osseous tissue, there was no evident reaction such as fibrous layer around the fibers. Scanning electron microscopy showed close apposition of vibrous tissue to velour (Fig. 6).

4.0 DISCUSSION & CONCLUSION

A rigid interface loaded directly on to bone, transmitted the load through a small fraction of the available trabeculae. This is likely to lead to overstressing, microfractures, and surface remodelling, accounting for the sclerotic line seen on x-ray. While the cement appeared to diffuse the loading, probably due to loading of subsurface trabeculae, the number of contacts was surprisingly even lower than for the rigid interface. Artefact may have been involved but certainly the number of contacts will be a function of the depth of cement penetration. However, as with a rigid interface, local trabecular overstressing is likely in some areas.

The compliant velour significantly increased the contacts by 59% compared with the rigid interface. It is suggested that this lead to a reasonably normal microstress distribution in the interface trabeculae, as well as over the surface as a whole. This was reflected in the lack of substantial trabecular remodelling, as would occur under overstressed conditions. Rather, there was some additional bone formation into the velour, to follow the fibrous ingrowth. The overall effect may be that the velour, reinforced with fibrous tissue, fulfilled the roles of distributing the stresses and isolating the bone from micromovements against the implant.

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ACKNOWLEDGEMENTS

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FIGURES.

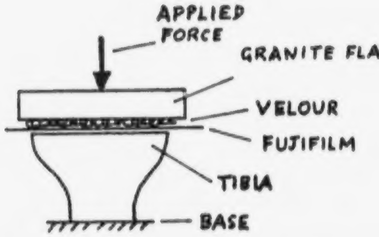

FIG. 1. Pressure Distribution on the Upper Tibia

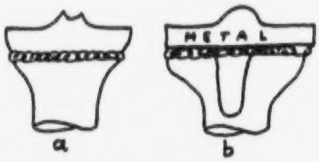

FIG. 2. The two animal (sheep) models for testing a velour interface.

FIG. 3. Optical Images of Pressure Patterns on Resected Tibial Surface
a. Rigid Interface
b. Velour Interface
c. Cement Interface

FIG. 4. At 2 months the velour is 50% engulfed with fibrous tissue.

FIG. 5. At 4 months there is some invasion of bone into the velour.

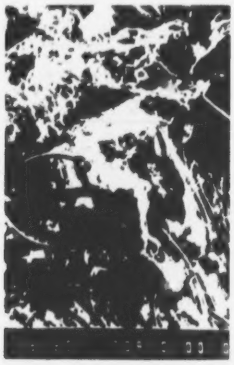

FIG. 6. Fibrous tissue invading the velour. The velour fibers are 15 μm diameter. Scanning electron micrograph.

SURGICAL SHOE ORTHOSES

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ABSTRACT - Some footwear problems traditionally provided with specially made boots or shoes can be satisfactorily, and more economically, treated with a thermoformed ankle foot orthosis made to fit ordinary shop-bought shoes or boots. Patient selection and design considerations are discussed.

RÉSUMÉ - Des problemes concernant la chaussure, qui sont traditionnellement pourvus de souliers ou de bottes particulierement fait sur mesure peuvent être traités, d'une manière satisfaisante et bien plus économique, avec une orthèse cheville-pied fabriqué d'un material thermoformable conforme aux souliers ou aux bottes courants du magasin. On débat du choix du patient et les considérations du dessin.

1. Introduction. Some problems, such as short and deformed feet and a foot fixed in equinus on a short leg, have traditionally been clothed in special custom-made footwear. This footwear is often ugly and it draws attention to the deformity by not being symmetrical with the other foot. If the functional requirements in each case are examined it can be found that supportive, or retentive forces supplied by the traditional shoe or boot can be supplied equally well by a plastic ankle foot orthosis (AFO). The lower portion of this AFO can be fashioned in a shape congruent with the inside shape of standard High Street footwear. Equally an internal shape can be fashioned to accommodate the deformed foot. If the space between these two shapes, internal and external, is filled with a suitable space filling material, such as a polyurethane foam (Fig. 1) one can achieve an arrangement which is functionally effective, cosmetically preferable (the patients can choose their own footwear within limits) and economically advantageous (the AFO costs much less than conventional surgical shoes and in a National Health Service situation such as prevails in Britain, the patient (rather than the state) happily pays for his own footwear).

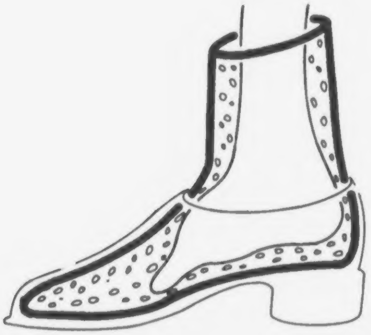

Figure 1

2. An Example. The technique is best described by reference to an example. The foot outlined in Figure 2 belongs to a 16 year old girl and is virtually rigid at the ankle and subtalar joints. The toes can be extended passively to 30° and can flex to 40° with half normal power. The knee and hip are normal, the calf muscle wasted. There is a shortening of the leg (80% below the knee) so that when standing in bare feet with pelvis level, the ball of the foot is 1cm above the ground. The functional requirements are, therefore, (a) to retain on the foot a cosmetically acceptable form of footwear, (b) to transmit from the leg and foot to the shoe the required sagittal plane forces ranging from a backward rolling moment following heel strike to a forward rolling moment during push off, (c) to provide adequate lateral (coronal plane) stability over the whole shoe-foot-ankle complex (depends on width of heel etc. used), (d) to provide a comfortable seating for the foot, (e) to provide means to prevent the toe of the shoe from curling upwards and the upper of the toe from collapsing inwards.

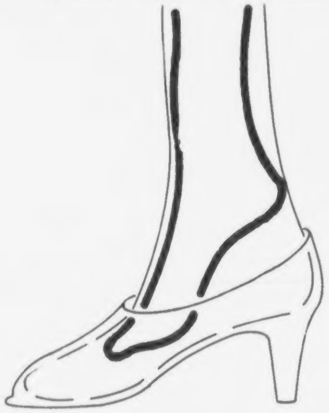

Figure 2

An ankle foot orthosis made in 3mm thick polypropylene with the following features will satisfy these requirements as indicated. The base and heel area of the AFO should have a shape which accurately fits the inside of the selected shoes (a & e). The toe area of the orthosis is filled to the inside shape of the toe of the shoe with a resilient material (e.g. flexible polyurethane foam) (e). The base of the AFO (shaped to the pitch of the shoe) should be stiffened with a second thickness of polypropylene or high molecular weight polyethylene such as ortholen (b & c). The upper areas of the AFO, made in 3 or 4mm polypropylene (a, b & c), should be shaped as far as possible to match the other ankle and lower leg. An anterior opening is provided for access and has straps for closing the opening firmly. The inside of the AFO contains a shaped filler in relatively rigid material under the heel and a resilient material elsewhere (a, b, c & d). It is shaped either directly to the foot or made to a cast of the foot.

3. Indications and Contra-Indications. There is clearly a space limitation in that the ankle-foot complex at the height at which it is required needs to be physically small enough to fit into the other shoe of the pair. If mobility at the ankle joint or its equivalent locus is present and needs to be preserved, a joint must be incorporated in the orthosis and the patient's own power of movement of the foot must be capable of overcoming the moments mentioned in 2(b) above, taking into account the new lever arms introduced by the presence of the longer shoe.

The lateral stability of the foot in the AFO must be sufficient not to require an abnormally wide base (heel and tread) which can only be achieved with non-standard footwear.

4. Results. This kind of treatment has been used at our Hospital and Institute now for a few years in more than 30 cases. When patients are carefully selected it appears to offer a very satisfactory form of treatment. The results of more than 400 patient-months of use indicate that the AFO generally outlasts the shoe or boot and can be transferred to a new one. The patient is invariably better pleased to select and purchase their own footwear and the method offers considerable economies over custom-made surgical footwear.

MICRO-PROCESSOR CONTROLLED ABOVE KNEE PROSTHESIS: ITS DEVELOPMENT AND EVALUATION

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ABSTRACT - A conventional above knee prosthesis with pneumatic cylinder is a prototype of the intelligent prosthesis with higher function. The pneumatic cylinder is controlled by a micro-processor and adaptively varies its dynamic response corresponding to walking speed, walking up and down stairs and so on. The optimum control theory is utilized to decide the valve opening sequence, being minimized into the built-in type including energy sources.

RÉSUMÉ - Une prothèse classique posée au-dessus du genou, avec cylindre pneumatique, est un prototype de la prothèse intelligente plus fonctionnelle. Le cylindre pneumatique est commandé par microprocesseur, sa réponse s'adaptant à la vitesse du marcheur, au fait que ce dernier monte ou descend un escalier, etc. La théorie de commande optimale est utilisée pour décider de l'ouverture de la soupape, les éléments du système étant réduits au minimum et intégrés dans la prothèse avec les sources d'énergie.

In the above-knee (A/K) prosthesis, the pneumatic cylinder is an attractive mechanical component which provides comparatively desirable dynamic response and dumping feature during swing phase if a valve between upper and lower chambers is adjusted adequately [1]. The simulation using mathematical model which is built by the detailed mechanical consideration can tell us that the dynamic response of the cylinder is significantly sensitive to the rate of valve opening and its sequence [2]. Naturally, this gives rise to an idea that if the pneumatic valve can be controlled properly, then the A/K prosthesis can dynamically simlate the swinging motion of normal leg.

In order to examine the feasibility of the idea, the optimun control problem is formulated under the criterion that the prosthesis should swing as the normal leg in terms of the least square method. The optimum valve opening rates and its sequences are calculated by the dynamic programming technique to show that the motion of a valve is feasible if the sophisticated control system is introduced into valve opening mechanism. By means of the microprocessor and the related techniques, we can realize the idae and minimize the system components to be built in the prosthesis itself with less increase of its weight.

From practical point of view, it is not so easy yet to process the optimization in the real time calculation that an available method in the current state of the art is proposed in terms of the switching-mode procedure in which the appropriate data to a walking speed is selected from those computed in advance and is sent to the valve control system. For simplicity, the informations of walking condition are obtained only from the foot sensor system which counts the swing period to predict the following walking speed in each step. The energy source of the valve control system is a regulated gas pressure system using a small CO_2 bulb.

The System mk.1 operates under a single board computer of Z80 CPU and mk.2 under the single tip computer of 8751; in the former, the computer section should be backpacked but in the latter, it can be loaded in the prosthesis.

The developed systems are evaluated on the prosthesis simulater, experimentally and computationally as well as a few amputees and also on the non-amputees provided the simulated A/K prosthesis. The results show that the intelligent prosthesis developed can improve the performance significantly to make users easily adapt the walking speed variation. The system could be modified to include other modes such as walking up and down stairs and extended to an integrated prosthesis system which includes even the processes of fitting, practicing and so on.

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LA RÉTROACTION SENSORIELLE DANS LA RÉÉDUCATION D'AMPUTÉS DE JAMBE

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ABSTRACT - This study investigated the relative effectiveness of augmented sensory feedback and traditional therapeutic approach in the early training of weight-shifting activities of alderly below-knee amputees. Assessment of sway and weight-bearing patterns were performed on a strain gage type of force-plate. The two treatment modalities were shown to be equally effective ($p > .05$).

RÉSUMÉ - L'efficacité respective de la rétroaction sensorielle et de l'approche thérapeutique traditionnelle dans la rééducation de la latéralisation et de l'équilibre orthostatique d'un groupe âgé d'amputés de jambe a été évaluée à l'aide d'une plate-forme de forces. Aucune différence significative ($p > .05$) n'a été décelée entre les modalités utilisées.

En orthostatisme, les variations du tonus musculaire nécessaire au maintien de l'équilibre vertical résultent de l'intégration, par les centres moteurs, de multiples afférences périphériques provenant des systèmes extéroceptif, proprioceptif, vestibulaire et visuel[2,7,8].

Les effets conjugués du processus de vieillissement et de l'amputation d'un membre de soutien sur l'organisation de ces systèmes semblent compliquer la recalibration des fonctions posturales de l'amputé âgé. En effet, les méthodes traditionnelles de traitement s'avèrent peu efficaces dans la rééducation de la latéralisation et de l'équilibre debout de l'amputé du membre inférieur et tout particulièrement pour l'amputé de jambe. Des instabilités et asymétries posturales, tant en position orthostatique[1,4] que lors de la marche avec prothèse[3,9] ont été observées chez des amputés appareillés depuis de nombreuses années. De plus, un taux exceptionnellement élevé d'échecs a été noté suite à la rééducation de l'amputé âgé du membre inférieur[5]. Il est à noter que chez ces derniers, l'handicap relève également du caractère diffus et évolutif des maladies vasculaires.

Compte tenu de l'augmentation de la longévité (3 à 5 ans) suite à l'amputation, tous les efforts de réadaptation sont justifiés pour améliorer la qualité de vie de l'amputé[13]. Il faut s'efforcer d'élaborer pour l'amputé la solution de réadaptation la plus favorable et la plus rapide. La rétroaction sensorielle semble être une solution[6,10,12].

Ce projet pilote, mené à l'Institut de réadaptation de Montréal, visait à évaluer l'effet de la rétroaction sensorielle dans la rééducation de l'équilibre debout d'un groupe âgé d'amputés de jambes ($\bar{x}$ = 63 ans) comparativement à une modalité thérapeutique de type traditionnelle.

Les sujets nouvellement appareillés et souffrant tous de problèmes vasculaires périphériques ont été répartis de façon aléatoire en deux groupes. L'équilibre des sujets du groupe témoin ($n = 6$) a été rééduqué de façon traditionnelle[11] alors que pour le groupe expérimental ($n = 5$), un appareil de rétroaction sensoriel inséré sous le pied prothétique, le limb load monitor, informait l'amputé de la charge mise sur la prothèse lors d'activités d'équilibration.

Avant et après cette série d'interventions, l'équilibre debout de chacun des sujets, yeux ouverts et yeux fermés, a été quantifié à l'aide d'une plate-forme de forces. Le système de mesure était conçu pour déterminer le mode de déplacement du centre de masse corporel au-dessus de la base de sustentation et le mode de répartition des charges corporelles sur les jambes.

Dans la première phase de l'entraînement prothétique d'un groupe âgé d'amputés de jambe, l'approche traditionnelle s'avère aussi efficace que la rétroaction sensorielle ($p > .05$) dans la rééducation de l'équilibre orthostatique. La forte variabilité inter et intra-sujets de la mesure, le nombre limité des sujets et la courte durée de l'intervention (8 jours) peuvent expliquer le non rejet de l'hypothèse nulle. De plus, à cause de problèmes inhérents à l'appareillage, certains sujets ont dû être freinés dans leur évolution.

Ces résultats s'opposent à ceux rapportés dans la littérature qui, eux, attribuent à la rétroaction sensorielle une certaine supériorité en rapport à l'approche traditionnelle[6,10,12]. Certains chercheurs soutiennent que la rétroaction sensorielle favorise l'apprentissage de la latéralisation en orthostatisme et à la marche, tout en réduisant le temps de l'apprentissage[10,12]. Cependant, le groupe d'âge des sujets étudiés et les pathologies sélectionnées imposent des limites quant aux comparaisons avec les résultats actuels.

De plus, nul n'a considéré le mode de déplacement du centre de masse corporel au-dessus de la base de sustentation comme variable.

Il importe toutefois de souligner que, dans la présente étude, l'avantage de la rétroaction sensorielle réside dans la possibilité de quantifier la mise-en-charge sur les membres inférieurs en cours de traitement, et par conséquent, dans les cas où le moignon est hypoesthésique et sujet aux plaies de pression, l'ampleur des charges transmises au moignon peuvent être contrôlées, voir même diminuées.

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SUCTION SUSPENSION FOR BELOW-KNEE PROSTHESES

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ABSTRACT - Results of surveys of AOPA prosthetists and BK suction socket wearers are reported. Benefits and problems are discussed, followed by recommendations for more widespread usage.

RÉSUMÉ - Les résultats des sondages des prothésistes de l'AOPA et des porteurs de manchons à succion BK sont décrits. Les avantages et les problèmes sont abordés; les auteurs proposent ensuite des recommandations concernant un élargissement de l'utilisation de ces manchons.

INTRODUCTION

Suction suspension of prostheses has been in use at least since the First World War and became widespread for above-knee (AK) prostheses in Germany by the 1930's and in North America in the 1950's (2). Experimentation with suction suspension for below-knee (BK) prostheses has also been carried out since the 1950's (5), with varying degrees of success, resulting in only limited usage by prosthetists. The advantages of this type of suspension have periodically led to recommendations for its further development (2,6). Although only a minority of prosthetists utilize suction supension for BK amputees, when applied successfully, it is met with enthusiasm by both prosthetists and amputees. Because of this, we undertook surveys of a group of BK suction socket wearers and a group of prosthetists to explore the benefits and problems involved in the use of this prosthesis.

A number of variations on the PTB design have successfully incorporated suction suspension (1,4,5). The suction prosthesis is secured to the leg by the small decrease in pressure inside the closed socket when the limb is lifted from the ground.

A major advantage of suction suspension is the maintenance of total contact with no "pistoning" or friction at the socket-skin interface. A second major advantage with suction suspension is an improvement in blood circulation in the residual limb as a result of the cyclical pressure changes during walking (1,7). Healing of persistent skin lesions has been reported following use of the suction socket prosthesis (4). The closer suspension and improved skin condition in turn allows an increased activity level. In addition, better control of the prosthesis is possible, as well as improved sensory feedback of limb position(2).

There are several factors that make applying suction suspension to the BK prosthesis more difficult than to the AK limb. An accurate total contact fit is essential for comfort and the maintenance of suction, but characteristics of the BK residual limb make this difficult. In addition, proximal constriction or excessive unremitting negative pressures may cause edema.

METHODS and RESULTS

In order to explore the experience of wearers of the BK suction socket a questionnaire survey was conducted of amputees fitted by four prosthetists making a leather lined suction socket with an expulsion valve, worn with optional latex suspension sleeve and no stump sock. The 56 respondents (a 71% response rate) included 49 males and 7 females with a mean age of 50 years, who had used suction suspension an average of nine years.

The response to the suction socket prosthesis was overwhelmingly positive. A number of questions asked the repondent to compare her/his suction socket prosthesis to previously worn limbs. Fifty-three said they preferred their suction socket limb with only one preferring a previous limb. With regard to skin condition, 56% felt it had improved, while 7% felt it was worse. On the question of residual limb pain, 70% reported less pain than before, 25% felt their pain was unchanged, and none felt they had more pain. The limb felt lighter in weight to 64% of the sample, while 59% felt the suction limb had a better appearance. The majority saw their prosthetist for adjustments or repairs one or two times per year with 80% saying this was no more often than for previous limbs.

When asked by an open-ended question what they liked about the suction socket, 45% mentioned an improved suspension or lack of pistoning. Other frequent comments were: increased comfort (43%), no stump socks required (32%), fits better with less skin breakdown (32%), feels more natural or "like my own leg" (30%), allows increased mobility and activity (18%), and gives better control or a positive feeling of the ground (13%).

Complaints were less frequent than positive comments with socket fit problems mentioned most often (13%), and frequency of liner replacement next (11%). A more durable suspension sleeve was desired by 9% of the respondents.

Several questions showed significant improvements in activity levels. The suction prosthesis was worn for more hours per day by 57% while 82% felt they could walk farther. Twenty-eight amputees (50%) said they now can run, whereas only 16 (29%) said they could run with their previous prostheses. Half of the respondents also stated they could perform more activities now than they could before, with some adding that they could not do any additional activities, but they could perform better, or longer, or with less pain. The group included many amputees active in sports with one woman who can now run three miles without pain, and a man who had achieved the black belt Competitor of the Year award from the Calornia Karate League.

On the basis of this survey it appeared that for this group of amputees the suction socket prosthesis was successful in terms of increased activity levels and amputee satisfaction. This raised the question as to why it has not gained wider use and popularity among prosthetists.

A survey was sent to 1185 certified prosthetist members of the American Orthotist Prosthetist Association. The results of this survey indicated a general lack of familiarity with the suction socket technique. Of the 466 respondents (a 39% response rate) 29% said they had had no contact, 20% had only heard about the technique, 9% had read about it, 21% had seen one, and only 22% had made some form of BK suction socket. In this latter category 13% said they had made a suction socket to be worn without a sock, and 8% had made a "sock" version of the limb. Most indicated they had only tried a few suction limbs, and often it was by chance discovered that a particular limb could be suspended without a strap. The judged success of the suction limbs by those familiar with the outcome was 63% successful, 26% not successful, and 11% mixed success (for more than one limb). Additional information on the technique was spontaneously requested by 10% of those sampled.

When asked their opinions on the suction socket, 55% held a favorable opinion, 10% were "unfavorable," and 35% had "no opinion." The attitudes of those who had made sockless suction prostheses were generally more positive with 85% feeling favorable. The success rate of this group was 49%, with 17% mixed success, 25% not successful and 8% success unknown. The opinions of the 39 prosthetists who had made sock versions of the suction limb were extremely favorable with a 72% success rate and only 3% reporting an unfavorable opinion.

The prosthetists were asked for comments and anticipated disadvantages with the suction socket. Consistent with the survey of BK suction socket wearers, the most frequent positive comment was the high degree of amputee acceptance and satisfaction. Other positive responses referred to improved suspension with decreased pistoning, better skin condition, and increased activity levels.

Of the large number of specific disadvantages mentioned, the most frequent category (48% of 831 comments) referred to problems with fitting and socket adjustments due to characteristics of the BK residual limb such as lack of soft tissue, limb shape, and frequent limb volume fluctuations. The other most frequently anticipated problems were inadequate suspension (20% of comments), skin irritation/infection (9%), and perspiration problems (9%).

DISCUSSION

Based on these two surveys the following conclusions are drawn.

1. Suction suspension provides unique advantages for the BK amputee in terms of activity levels, comfort, and condition of the residual limb.
2. The technique has wide applicability but candidates must be carefully selected. The major requirements identified by prosthetists familiar with the technique are (a) reliable, motivated amputees, and (b) mature residual limbs (at least one year post-amputation).
3. Successful construction of this limb, especially versions made for use without socks, requires especially accurate fitting techniques by proficient prosthetists. Cast modifications slightly different from those for the standard PTB are required for success.
4. Additional prosthetic courses given by those who have mastered suction socket fitting and fabrication would greatly improve the utilization and success of this technique. Common problems have been solved and should not be left to trial and error, a common cause of failure with many attempting this type of prosthesis for the first time.

In conclusion, while suction suspension is not suitable for every amputee and prosthetist, it is a valuable option for those prosthetists who have the opportunity to learn the techniques.

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A SPRING-LOADED KNEE-ANKLE ORTHOSIS IN THE MANAGEMENT OF DUCHENNE MUSCULAR DYSTROPHY PATIENTS

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ABSTRACT - A knee-ankle orthosis designed for muscular dystrophy patients includes a spring-loaded knee joint allowing flexion while ensuring stability during stance. It provides a more natural gait than that using conventional orthoses and has been optimized for knee stability and is presently being clinically evaluated.

RÉSUMÉ - Une orthèse fémorale dynamique a été conçue pour répondre aux besoins des patients atteints de dystrophie musculaire de Duchenne. Un câble élastique situé à l'articulation du genou permet sa flexion sans toute fois nuire à la stabilité du membre inférieur. Ce concept est présentement évalué en clinique.

INTRODUCTION

Ischial weight bearing knee-ankle orthoses (kao) are currently used in the management of patients with lower extremity instabilities. They are still prescribed to Duchenne muscular dystrophy patients even though they often contribute to an awkward gait pattern by locking the leg in complete extension during ambulation.

It has been shown previously in a gait analysis study (Allard et al., 1981) that the vertical hip oscillation of a patient was increased by almost 65% during gait using the conventional orthoses from that without them. To perform a walking step, the patient had to circumduct the extended leg while his whole weight was borne by the other. In the same study, the lateral trunk sway (i.e., the angle subtended by a straight line joining the neck to the hip joint and the vertical, during a gait cycle) of the conventionally braced patients had a range more than twice than that of the unbraced patient. This can be explained in part by the absence of knee flexion.

There have been several attempts to improve the conventional kao and adapt it to enable a more natural pattern of locomotion. They introduce new concepts such as hydraulic cylinders (Strohm et al., 1963), elastic cables (Glancy, 1976) and bands (Volkert, 1976). However, these devices do not fulfill the needs of muscular dystrophy patients who maintain their delicate balance by a postural hyperlordosis and who require bilateral orthoses.

This paper presents a kao specially adapted to stabilize the knees in extension during stance, assist in sitting down, and allow knee flexion while maintaining leg stability during gait.

DESIGN CONCEPT

The kao consists of a spring in the form of an elastic cord attached to a set of eccentric, articulated aluminium uprights and acting across the knee hinge joint of an otherwise conventional orthosis.

The elastic cord is prestressed to a determined tension to provide a resisting moment to knee flexion during stance and gait. The pretension of the spring may be periodically adjusted to allow optimal use of the subject's weakening muscles for progressive myopathies. The eccentricity of the hinge joint provides a larger moment arm than that of a conventional hinge joint. As the knee flexes, the stabilizing moment is a function of the increasing instantaneous tension in the spring, its decreasing instanteneous moment arm and of the spring's mechanical properties.

MATHEMATICAL MODEL AND OPTIMIZATION

The stabilizing moment at the orthosis knee joint is expressed in terms of the following parameters given in the equation:

$$M(\theta) = d(\theta)\ N\ \{K\ (\Delta x(\theta) - \Delta x_o) + f\}$$

where the moment, M, the moment arm, d, and the spring extension, Δx, are functions of flexion angle, θ, and depend on the location of the upper and lower anchoring points with respect to the knee joint center of rotation at full extension ($\theta=0$). N represents the number of springs used, K the spring constant, and f the initial force stretching the spring by a length of Δx_o.

Using the above equation, the brace knee moment is calculated over a gait cycle to predict its performance. Afterwards, a nonlinear exploratory technique, the SIMPLEX method (Siddhall, 1972), was used to minimize the difference between the computed and reference knee moments (Eberhard, 1954). Because the highest knee moments normally occur during the stance phase, the orthosis moment was only optimized for that portion of the gait cycle.

RESULTS AND DISCUSSION

The best match between the orthosis knee moments and the reference moments occured during the latter part of the stance phase. Immediately after heel-strike, the computed knee moments were 35% lower than those of the referenced. This suggests that knee instability during heel-strike would occur with this design if the average speed of locomotion is not altered. During most of the swing phase, the orthosis knee moments were almost twice those of the corresponding reference moments implying that total knee entension would occur.

To verify the concept, a nine-year-old Duchenne muscular dystrophy patient was fitted with the dynamic kao. As expected, the orthosis allowed the patient to flex his knees during the stance phase and also permitted him to sit down much more easily than with the cumbersome conventional kao. As for the knee instability during heel-strike and total knee extension during the swing phase, the patient compensated them by a reduction in his speed of ambulation.

In an attempt to improve the described orthosis, modifications shown in Fig. 1 have been made: a pin and pulley system is attached to the hinge joint, the anchoring points for the elastic cord are relocated, and a steel cable replaces part of the length of the elastic cord.

To provide knee stability immediately following heel-strike, the pretension in the elastic cord is increased to generate a higher moment than with the previous design. To allow flexion during the swing phase, the anchoring points of the elastic cord have been relocated in such a manner as to provide a zero knee moment when knee flexion reaches approximately 25°, only encountered shortly after push off. At this point and beyond, the steel cable connected to the elastic cord bends and is kept at the toggle point by use of the pin and pulley system, shown in Figs. 1A, to 1C. A constant zero moment is maintained even with a stretched elastic cord since the moment arm is nonexistent. The knee joint is free to flex during the early swing phase up to its maximum range. During the later swing phase the weight of the shank and its momentum initiate an extension movement of the leg. As the steel cable begins to move away from the pin and pulley system, the moment is gradually increased contributing to reach full extension of the leg. The 27 N-m moment provided by the orthosis fully extended prepares the lower limb for heel-strike. During stance, knee stability is obtained once more by means of the elastic cord. In the sitting position shown in Fig. 1C, the knee moment is zero.

A propotype knee hinge joint, shown in Fig. 2, has been fabricated and is currently being fitted to a Duchenne muscular dystrophy patient. The performance of the orthosis during gait is being clinically evaluated.

ACKNOWLEDGEMENTS - The financial support of the Muscular Dystrophy Association of Canada is greatly appreciated.

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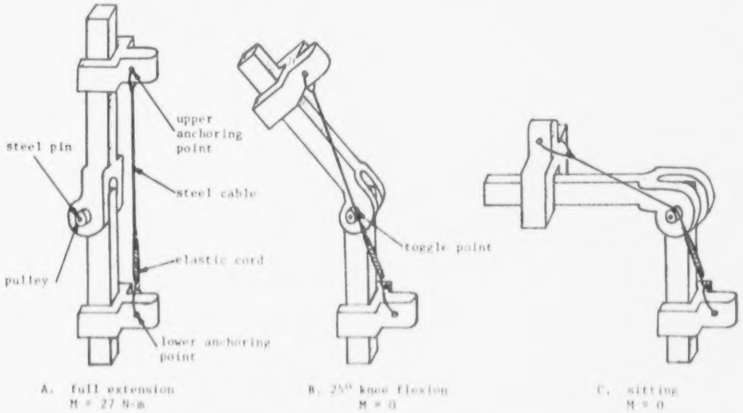

A. full extension
M = 27 N-m

B. 25° knee flexion
M = 0

C. sitting
M = 0

Fig. 1. Schematic representation of the knee joint prototype illustrating its function for different positions.

Fig. 2. Photograph of the spring-loaded knee joint.

DESIGN OF AN ORTHOTIC HINGE FOR THE KNEE CAPABLE OF PRODUCING NORMAL ANATOMIC MOTION OR NEAR ANATOMIC MOTION AS DESIRED

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ABSTRACT - This paper describes the design of orthotic hinges which are capable of reproducing the complex motion of the normal knee. Two designs are presented both of which use specially shaped parts to guide the motion of the hinge. The shapes of these special segments are computer generated to conform to 3-D description of knee motion. The motion input can either correspond to normal anatomical motion, or can be prescribed to suit a particular need.

RÉSUMÉ - Dans cette communication touchant le domaine des orthèses, on décrit des charnières capables de reproduire les mouvements complexes du genou normal. Deux types sont présentés et tous deux sont munis de pièces de forme spéciale pour guider le mouvement des charnières. La forme de ces pièces spéciales a été obtenue par ordinateur pour qu'elle soit conforme à la description tridimensionnelle du mouvement du genou. On peut donner à ces charnières un mouvement qui correspond à un mouvemént anatomique normal ou à un mouvement qui répond à un besoin particulier.

INTRODUCTION.

The use of knee orthoses is traditionally as a protective device for the traumatically injured or the chronically deficient knee. The benifit derived from such devices is by restricting motion of the knee thereby preventing any abnormal motion which could further damage the knee. There are many knee brace designs currently on the market. These braces incorporate two basic hinge types; the fixed pivot type, and the polycentric type. The fixed pivot hinge mechanism allows the knee to flex-extend but does not provide for internal-external rotation, for varus-valgus rotation or for translational movement except through slippage of the orthosis and soft tissue motion. The polycentric hinge provides for the movement of the rotational center of the hinge as a function of flexion angle. Traditionally polycentric hinges are symmetrical, i.e. medial and lateral hinges are identical. This provides a translational movement of the knee as a function of flexion, however, internal-external rotation and varus-valgus rotation are only accommodated for through cuff slippage and soft tissue motion as with the fixed pivot hinge.

To obtain the full benefit of a knee orthosis, the hinges must accurately mimic the normal motion of the knee. Small deviations from this normal motion pattern may cause significant strain in the ligaments and result in soft tissue damage. Therefore, hinge design must take into account the complex three-dimentional kinematics of the knee.

The approach used in this investigation was to define the normal motion of the average knee in terms of a femoral axis through the posterior femoral condyles. From this kinematic definition, the medial and lateral hinges are designed seperately so when put together they reproduce this normal motion. Two possible hinge designs are presented. The new hinge designs are modular in the sense that the interchangability of one part can provide a different motion characteristic (simple or complex) to suit a particular need.

BACKGROUND.

A previous study (reported in a seperate paper) has shown that the posterior femoral condyles can be accurately modeled as spherical surfaces. The axis which connects the center points of these condylar spheres is defined as the femoral axis. The three-dimentional motion of the knee can be described by the motion of a moving axis system fixed in the femur relative to a reference axis system fixed in the tibia. A simplification of this system is shown in figure 1. In this system the femoral axis is tracked relative to the reference axis system as the knee flexes. Projecting the femoral axis onto an x-y plane produces a locus of points as a function of flexion angle.

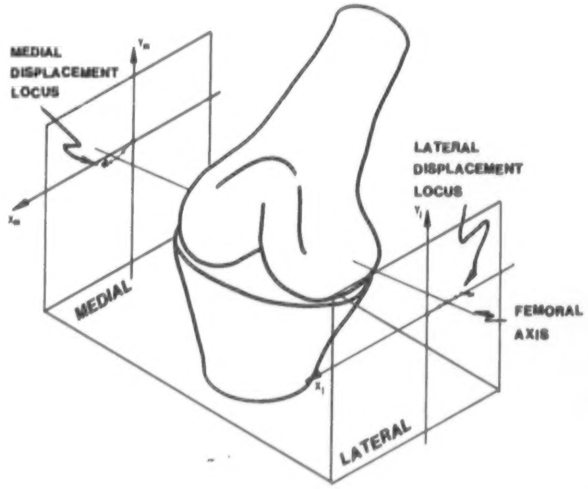

FIGURE 1: Femoral axis system used to define the kinematics of the knee.

Our previously mentioned study has provided data on the medial and lateral displacement loci of the femoral axis. This information can be used to design the medial and lateral hinges of an orthotic system. The system would work by forcing the femoral axis to conform to certain motion characteristics-- in this case normal knee motion.

CAM-SLOT DESIGN.

The cam-slot hinge design is composed of two functional components; the femoral component and the tibial component. The femoral component, when properly installed, has a pin which is coincident with the femoral axis. These two pins (one on the medial side and one on the lateral side) define the femoral axis and are forced to move in accordance with the normal motion of the femoral axis as measured experimentally. To ensure the normal motion of the femoral axis, the femoral pin rides in a slot in the tibial component. This tibial slot is the locus of points determined by the projection of the femoral axis onto an x-y plane at the position of the hinge. The femoral pin is properly positioned within the tibial slot, at all angles of flexion, by the action of a cam. The base of the femoral component is specially shaped to form this cam. The cam rides against two tibial follower pins during flexion-extension, thus constraining the motion. Figure 2.

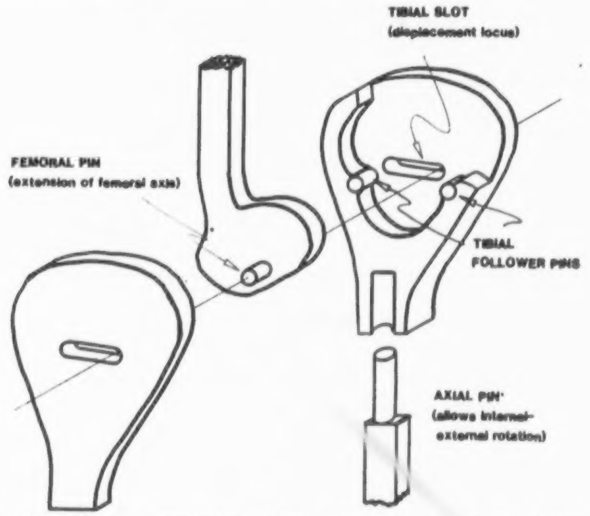

FIGURE 2: Exploded view of multi pin-slot hinge mechanism. Medial side is shown.

The medial and lateral hinges are designed seperately to provide the required motion of the femoral axis in the medial and lateral planes. These two hinges are in general not the same, and the extent to which they differ provides the rotational and translational motions to the knee. The large degree of internal-external rotation (approx. 20 degrees) is accommodated for in the cam-slot design by the addition of an axial hinge in the tibial component. Since varus-valgus rotations are minimal, no additional hinge was added, rather flexure of the orthosis is relied on to allow this motion.

The design of the individual cam shapes was performed using computer graphics and the following routine. A position is chosen for the location of a tibial follower pin and the successive positions of of that pin are mapped as the tibia is flexed about a fixed femur from full extension to full flexion. The formuae describing this motion are:

$$_xP_\theta = ({}_xD_\theta + X_o) \cos\theta + ({}_yD_\theta + Y_o) \sin\theta$$
$$_yP_\theta = -({}_xD_\theta + X_o) \sin\theta + ({}_yD_\theta + Y_o) \cos\theta$$

where:

$_xP_\theta$, $_yP_\theta$	are the x-y coordinates of the follower pin at flexion angle θ.
$_xD_\theta$, $_yD_\theta$	are the x-y displacements of the femoral axis at flexion angle θ.
X_o , Y_o	are the x-y coordinates of the follower pin at full extension.

A cam is thus formed by choosing the locations of the two tibial follower pins. The computer then generates the appropriate cam based on the femoral axis displacement requirements. A series of cam shapes can then be produced as the tibial follower pins are relocated to different positions. These resulting cams can be compared with one another and against certain criteria to reach a final design. The series of cams can also be redrawn using different motion characteristics to produce an orthosis which could provide special motion for a particular need.

MULTI PIN-SLOT DESIGN.

The multi pin-slot hinge design provides for the anatomical motion of the femoral axis without necessarially incorporating it as a pin in the orthosis. Once again the hinge mechanism has a femoral component and a tibial component. The femoral component has a series of pins protruding from its surface. The tibial component has a series of slots in which the femoral pins slide as the orthosis flexes or extends. The movement of the pins in the slots completely constrain the motion at all times. Under most circumstances it is possible for the slots to merge or cross without detriment to the motion. As with the cam-slot device, internal-external rotation is accommodated for by the addition of an axial hinge pin in the tibial component. Figure 3.

Computer graphics were used in the design of this hinge mechanism to determine the shapes of the slots which result from a particular pin arrangement. The slots were determined by the successive positioning of the pins as the femoral component was flexed about a fixed tibia. The following equations describe this motion:

$$_xP_\theta = {}_xD_\theta + X_o \cos\theta + Y_o \sin\theta$$
$$_yP_\theta = -X_o \sin\theta + {}_yD_\theta + Y_o \cos\theta$$

where the symbols have the same meanings as before.

The number of pins and the position of each pin can be varied to produce different hinge designs all of which produce the same motion. These designs can then be evaluated against one another and against certain design criteria to reach the ultimate hinge design.

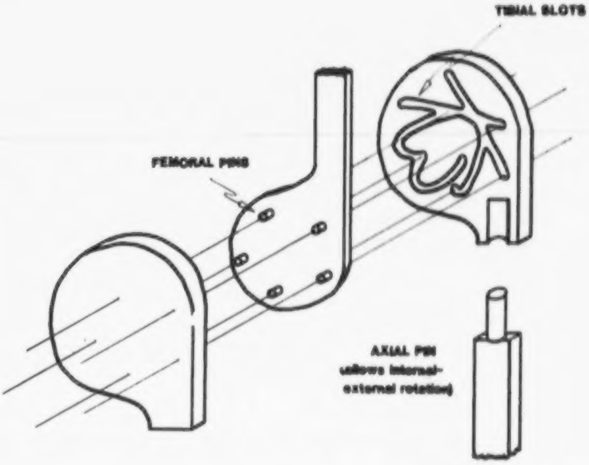

FIGURE 3: Exploded view of multi pin-slot hinge mechanism. This version uses five pins/slots. Lateral side is shown.

The prescribed motion characteristics of the hinge can be altered by providing a different definition of the flexion dependant femoral axis displacement. This new motion is incorporated into the hinge simply by interchangability of the slotted tibial housing. As such, the orthosis could be custom designed to the anatomical motion of a particular individual or to suit some special purpose.

DISCUSSION.

The femoral axis definition is a useful way in which to design an orthotic hinge. Tracking this axis as a function of flexion, describes all but one of the remaining degrees of freedom; internal-external rotation, varus-valgus rotation, anterior-posterior translation, and inferior-superior translation. The one aspect of the knee kinematics not included is medial-lateral translation. Medial-lateral translations have been ignored since they are difficult to incorporate into the hinge design, and since they are normally quite small. The result is an orthotic system which accurately guides the normal three-dimensional motion of the knee.

Design of the hinge mechanisms on computer, allows a large number of possible designs to be produced and also allows evaluation of the individual designs based on certain criteria. The important criteria are: accurate, fully defined motion; ease of operation; strength/stiffness; small size; ease of manufacture; long, maintanence-free life; noiseless operation; cosmetic.

The method of attachment of the orthosis to the leg will be included in further design of this orthosis system. The design of suitable cuffs introduce further criteria for evaluation. The cuffs must have adequate strength/stiffness to provide controlled motion; must grip the leg firmly without slipping, even during vigorous activity, and they must be easy to don and doff.

CONCLUSION.

Two hinge designs have been presented for a knee orthosis which provides anatomical motion. The hinge mechanisms were designed using computer graphics and the measured motion of the femoral axis. The hinges incorporate internal-external rotation, limited varus-valgus rotation, and translations in the X and Y directions. Furthermore the hinges are modular and can be "programmed" to produce different motion pattern by the interchangability of a single part.

ACKNOWLEDGEMENTS.

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MECHANISM NUMBER SIX AS A POLYCENTRIC PROSTHETIC JOINT

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ABSTRACT - The paper presents design of a new polycentric knee mechanism using mechanism number six. This kinematic linkage exhibits an overall centrode behavior which matches with that of the actual human knee motion. In this paper, the motivations and the procedure which led to the use of mechanism number six as a knee prosthetic device are discussed.

RÉSUMÉ - La communication présente la conception d'un nouveau genou polycentrique utilisant le mécanisme n° 6. Cette articulation dynamique a un comportement général de centrode qui correspond à celui du mouvement réel du genou humain. Dans cette communication, les motifs et les méthodes qui ont entraîné l'utilisation du mécanisme n° 6 comme prothèse de genou sont abordés.

Polycentric motion is said to occur when the center of rotation of two bodies undergoing relative motion changes location. For the plane motion the locus of instant center traces two curves on the two bodies known as centrodes. The motion itself can be completely duplicated by the pure rolling of one of the centrodes on the other. Most joints in the human body are polycentric and many of these have been studied in order to design better prosthetic devices [1,2,3]. The human knee joint shown in Figure 1 is a subject of frequent study. The figure shows that the initial contact between the centrodes occurs at a point well above anatomical center of the knee. This contact point moves downward when the flexion of the knee takes place from a fully extended position. As the tibia rotates about the femur in flexion, the eccentric portion of the distal portion of the femoral condyle causes the center of rotation to displace distally and posteriorly during the first 20 degrees of flexion. The center of rotation displaces proximally and anteriorly as the knee rotates from flexion to full extension. This makes a human knee a polycentric joint and there are several mechanisms which exhibit similar polycentric behavior. Traditionally the knee joint has been single axis type which has provided acceptable function for several amputees. In case of single axis joint, the amputee must walk over a fully extended knee during weight bearing which is physiologically abnormal and contributes to unnatural appearing gait of the above knee amputee. This and other shortcomings of the single axis type joint have lead the designers to seek other mechanism knee devices. Of the thirty-two commercially available artificial legs, only six contain polycentric knee joints [4]. Most of these polycentric mechanisms use four-bar or six-bar linkages containing only revolute pairs. Substitution of one or more revolute pairs with sliding pairs can provide an excellent alternative to the four revolute mechanism. Shoup [5] has suggested the use of the Oldham Mechanism as a polycentric joint. It is the purpose of this paper to present a new prosthetic knee mechanism which uses mechanism no. six containing two prismatic and two revolute pairs.

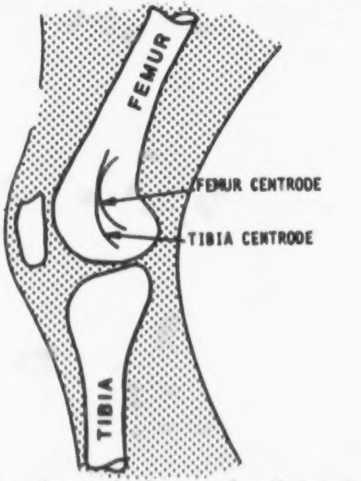

Figure 1. Centrode Curves for Human Knee.

Mechanism no. six, also known as opposite double slider, is shown in Figure 2. This mechanism resembles a slider crank mechanism except that the revolute pair of the slider crank is replaced

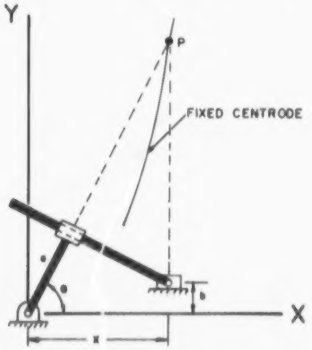

Figure 2. Mechanism Number Six.

by a prismatic pair. As the mechanism moves, the location of the instant center moves generating the fixed centrode as shown in Figure 2. Mechansim no. six is not presently in use as a polycentric joint. However, its simple design and overall centrode behavior make it a desirable candidate for use as a polycentric joint. The centrodes for this mechanism have been determined to be 4th order polynomial curves [6]. The techniques available to perform the dimensional synthesis of four link mechanisms for polycentric action are limited and tend to use optimization methods [7]. Shoup and Sodhi have used the straightforward curve matching technique to design polycentric mechanisms [8]. That method is used in this paper to develop the mechanism no. six as a polycentric knee mechanism. Due to space limitations the details of the synthesis procedure are not given here. To perform the dimensional synthesis of the mechanism several centrode plots are developed by varying the dimensions of the linkage for each curve. The shape of the centrode curve obtained from the experimental data on actual human knee motion is drawn on a transparent paper which is overlayed on the centrode plots for mechanism no. six and the best match is obtained as shown in Figure 3.

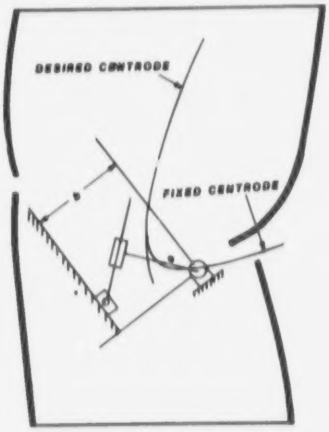

Figure 3. Knee Joint Centrode Matching.

The slider surface and the fixed pivot is attached to the lower portion of the limb and the coupler is attached to the upper portion as illustrated in Figure 4. Due to the motion constraints in mechanism no. six the desired centrode behavior and the 96° angular flexion of the knee joint are simultaneously obtainable. More work needs to be done to use this mechanism as a human knee joint. The solution would have to be further synthesized for design compatibility in terms of force transmission characteristics and other constraints which accompany problems of this type.

Presented in this paper is a conceptual design of a polycentric knee mechanism using mechanism no. six. This mechanism exhibits an overall centrode behavior which matches with that of the actual human knee motion. The mechanism is simple in design and construction which is a plus for reliability. Instead of using four revolute pairs, the mechanism employs two prismatic pairs, and two revolute pairs which is a desirable characteristic in machine design. The mechanism can be used for the above knee amputee as it does not require too much space. The mechanism is quite condensed and so should provide a more natural appearance at the knee.

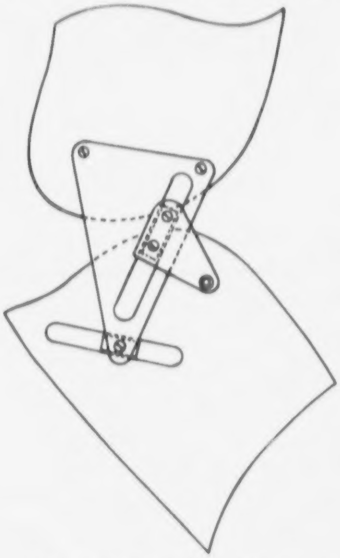

Figure 4. Mechanism Number Six as a Polycentric Knee Joint.

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THE MOTION OF ORTHOTIC DEVICES AND HINGE-DISTRACTORS FOR THE KNEE JOINT

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There are several advantages in accurate reproduction of motion in an external knee linkage. The motion of the thigh and shank cuffs on the skin should be reduced. The ligaments will be better protected, especially important after injury or reconstructive surgery. Joint surface compatability is essential in a hinge distractor which is fixed to the bones by pins.

A method for describing knee motion is described which involved computer modelling of geometry. A motion study was carried out on specimens and volunteers. Surprisingly, posterior and anterior translations were determined to be necessary on the lateral and medial sides respectively. The motion pattern was related conceptually to a cam-slot-pin family of designs, which were shown to be amenable to computer-aided design.

INTRODUCTION. Orthotic devices for the knee are prescribed for a variety of applications, such as chronic instability, protection after a traumatic injury, protection after a surgical procedure, or after a prosthetic replacement. Hinge distractors have been applied to treat ankyloses or after internal bone injury.[1] The stability requirements vary with the indications. However, it is generally the case that the external linkage should guide the knee motion in a reasonably normal pattern. This is to prevent unwanted tensions and force on the soft tissue and joint surfaces, and to minimize cuff-to-skin motion and rubbing. Many orthoses use a single axis hinge on each side of the joint, but polycentric designs are now increasing in usage. Polycentric motion is achieved with a double axis pin joint, with pins-in-slots, or with cams. However, such arrangements do not account for the internal-external rotation of the joint[2],[3], while placement, which should be critical, is an approximation. Thus, key questions for external orthoses and hinge distractors are what external points should be guided, what is their normal motion, and to what boney landmarks can the joints be lined up with?

MATERIALS AND METHODS. To determine boney references on the femur for axis definition, 22 distal femurs were aligned in a box with the distal and posterior condyles on mutually perpendicular planes, embedded in plaster, and cut into 16 equal sagittal slices (Fig. 1). The 17 sections of each bone were digitized into a computer. The points which would articulate on the tibia from 15-105° flexion of sections$^{3-6}$ (lateral) and 12-15 (medial) were determined. The best-fit spherical surface was completed by iterations of x,y,z of the center and radius r, using an optimization technique. The criterion was the minimum sum of the absolute distances of the points to the sphere. On 14 other knees, the sagittal radii of the posterior condyles were measured, and in frontal profiles at 0,30, 60,90° of flexion. Radius gauges spaced by 1mm, enclosing a 90° arc, were used. The medial-lateral spacing of the condyles was also measured.

Motion measurements were made on specimens and on normal subjects. The 14 fresh intact knees were mounted in a rig[4] and sagittal x-rays were taken from 0 to 120° flexion under quadriceps tension. Key reference points were digitized, as well as 6 points on the lateral and medial femoral condyle condyle peripheries. The center of the best-fit circular arc was computed. A similar analysis was carried out from movie x-rays of 8 normal males ascending a steep step.

The two line joining the centers of the medial and lateral 'spheres' defined the femoral x-axis, the y-axis was vertical at 0° flexion, and the z-axis was anterior at 0° flexion. The fixed axis system was in the tibia, and the moving axes in the femur coincided at 0° flexion. Using an Eulerian angle system[5] with minor approximations internal-external rotation, varus-valgus, anterior-posterior and vertical translations, were computed as a function of flexion angle. Accuracy analysis showed the centers of the circular arcs were to ±1mm for specimens and ±1.5mm for volunteers.

RESULTS. a. Geometry. The geometry was standardized to a medial-lateral femoral dimension of 80mm, and an anterior-posterior tibial dimension of 50mm[6]. The points on the lateral and medial condyles deviated from the best fit sphere by only 0.53±.20 and 0.63±.22mm respectively (Fig. 2). Overall results for spherical and profile radii were:

	Lat.Rad. ±SD(mm)	Med.Rad. ±SD(mm)	M-L Spacing of 'Spheres'mm
22 femurs, sphere computer analysis	19.18±1.67	20.82±2.4	48.63
14 knees, sagittal radius-gauge	20.4 ±2.05	19.9 ±1.7	45.9±3.5
14 knees, sagittal radiography (1.5mm cartilage)	20.8 ±1.8	19.6 ±1.6	-

Thus, the posterior condyles of the average femur can be accurately modelled as two spherical surfaces of radius 20mm and spacing 46mm. To describe motion, the moving axis system in the femur is defined as coincident with the fixed axis system in the tibia, with the knee in extension. The axes in extension are: the tranverse axis through the sphere centers, and an anterior-posterior and vertical axis mutually perpendicular (Fig. 3). The motion is described by Eulerian angles (flexion-extension, varus-valgus, internal-external rotation) and x,y,z displacements of the moving axis origin relative to the fixed axes. The motion of the knee specimens from 0-120° showed a posterior displacement of the femoral origin of 7.4mm: the lateral sphere center moved back 17.0mm, but the medial sphere center moved forward 4.5mm to mid-range then back to a net 2.2mm (Fig. 3). The transverse femoral axis rotated 20.2° on average (equivalent to an internal tibial rotation). The origin moved downward net 2mm from 0.-120° flexion, most occurring from 0-30° flexion. From 0-45° flexion, there was a 4.2° varus movement of the femoral axis, thereafter decreasing to 2.2°.

The motion in the volunteers was statistically indistinguishable ($p<.01$) from that of the specimens. The lateral sphere center moved back 14.1mm and the medial forward net .3mm. Transverse rotation was 16.9°.

The motion can be depicted, as in Fig. 5, as the movement of the transverse femoral axis relative to the tibia as a function of flexion angle. The principal motions were the anterior-posterior translation and the external rotation. By comparison, varus-valgus rotation and vertical and medial-lateral translations were small.

APPLICATION TO EXTERNAL LINKAGE DESIGN

When the transverse axis was projected out to the side of the knee where the linakge is located, the anterior-posterior displacements were magnified. In flexing from 0-120°, the lateral side moves backwards 22-30mm, while the medial side moves forward 14-20mm. (The range recognizes size variations and variations between specimens.) For linkage design, the rotations and translations (P) were expressed as a function of flexion (F) by curve-fitting from the data in the formula:

$$P=a.+bF+cF^2+F^3.$$

As discussed above, many mechanisms can be used to obtain the required motion. Our criteria were:

adequate accuracy of motion;
allows variations of motion;
ease of manufacture;
cosmetic and light;
self-lubricating and low wear;
and adequate strength.

The mechanism is described conceptually in Fig. 6. Lateral and medial femoral and tibial components are attached to the leg with cuffs. In extension the femoral pins are aligned with the transverse x-axis using radiography. In the YZ plane, anterior-posterior motion along Z is defined by a cam guiding the femoral component together with the pin in the slot. Motion along Y and varus-valgus can be closely approximated by a tilt of the slots in the YZ sagittal plane. Internal-external rotation is accomplished by a rotation axis in the tibial component. This however produces incompatibility of a few mms in medial-lateral across the joint displacements but this can be readily taken up by slight flexibility of the cuffs.

The design of the cam and slot, as well as alternate designs using a cam in a housing, and 2 or more pins in slots, were investigated using computer graphics. Motions in the YZ plane were described by standard coordinate transformation matrices[7]. This will be described in a separate paper.

SUMMARY AND CONCLUSIONS. 1) External knee linkage for orthoses or hinge-distraction need to accurately guide motion for ligament and surface compatibility; 2) Motion was measured on specimens and volunteers in reference to readily identified axes; 3) In flexion, the lateral femoral displacement was posterior while the medial side showed anterior displacement; 4) A conceptual design of linkage to obtain normal motion was designed.

ACKNOWLEDGEMENTS. The work was supported by Veterans Administration, R.E.R. & D. Grant #104-46-6320-003.

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FIGURES.

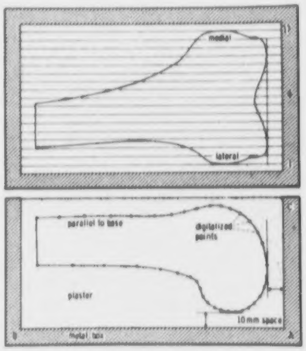

FIG. 1. The method of embedding and sectioning the distal femurs.

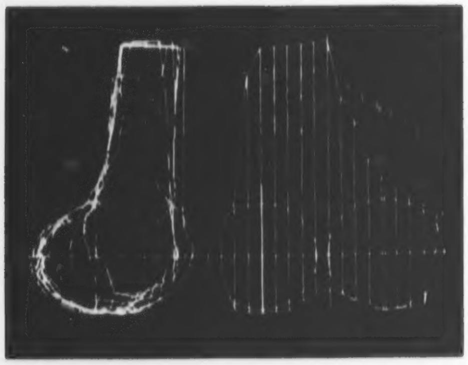

FIG. 2. A typical computer display of the 17 sections and best-fit spherical outlines.

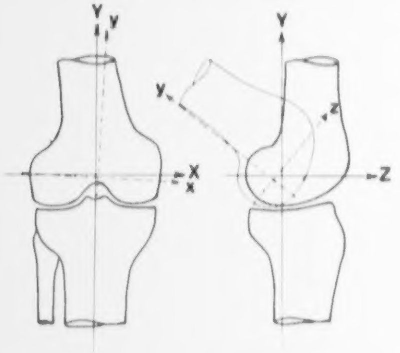

FIG. 3. Definition of axes: fixed in the tibia, moving in the femur.

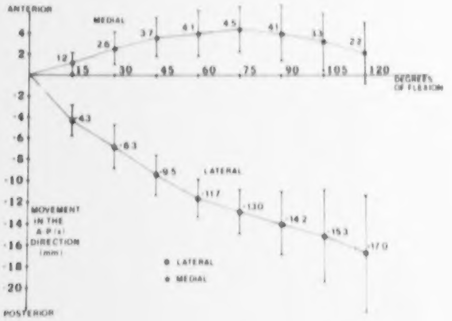

FIG. 4. Anterior-posterior motion of the lateral and medial sphere centers.

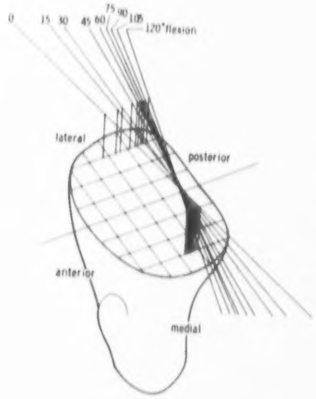
0
15
30
45
60
75
90
105
120° flexion
lateral
posterior
anterior
medial

FIG. 5. Movement of the transverse femoral axis projected out to the location of an external linkage.

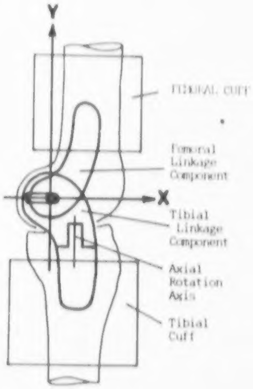
Y
X
TIBIAL CUFF
Femoral Linkage Component
Tibial Linkage Component
Axial Rotation Axis
Tibial Cuff

FIG. 6. Conceptual design of a knee brace.

CONTROL OF ALIGNMENT AND SOCKET FIT OF BELOW KNEE PROSTHESES WITH THE AID OF FORCEPLATES

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J. Mizrahi, Department of Biomedical Engineering Technion, Haifa, Israel

ABSTRACT - The present work is part of a continuing study, the aim of which is to establish objective criteria for delivery of leg prostheses. Records of amputees were reviewed and, their ground reaction forces during gait and the kinematics were recorded and processed. The variations in the calculated impulses of the forces and other variables were studied. Some basic criteria for instrumented and computerized procedures for quality control of prostheses were developed.

RÉSUMÉ - S'inscrivant dans le cadre d'une étude permanente, le présent travail vise à établir les critères objectifs de la mise en place d'une prothèse de jambe. Pour ce faire, on passe en revue les dossiers des amputés, et on relève et traite les données sur les forces de réaction au sol durant la démarche, et sur le comportement cinématique. On étudie les variations des impulsions calculées correspondant aux forces et aux autres variables. On élabore les critères de base pour les procédures de contrôle informatique ou physique de la qualité des prothèses.

INTRODUCTION

A successful delivery of a below knee leg prosthesis depends on two major variables:

1. Adequacy of the stump prosthesis interface.
2. Alignment of the prosthesis.

The socket which interfaces the prosthesis to the stump is fabricated according to certain guidelines which are aimed at optimizing the load transmission between the prosthesis and the skeleton, through the soft tissue. The alignment is aimed at positioning the prosthetic components in their most desirable state. The interface and the alignment aspects are currently treated more as an art rather, than as a scientifically established technology, see Foort (1979); Berme (1978). A great deal depends on the skills and intuition of the prosthetic technician although, some established routines do exist for the correct forming of the socket and aligning the prosthesis.

Alignment and socket fitting may create similar effects. Some states of misalignment may be interpreted as wrong socket fit due to inadequate force transmission through the interface. Basically, wrong alignment may effect the load transmission as well as the kinetic behavior of the prosthesis.

The aim of the present work is to help develop a control procedure of delivery for leg prostheses, in which ground reaction forces will serve as the main dependent variable.

Experimental Procedure

In this study, only forces were documented systematically. For the measurement of the ground reaction forces, two "Kistler" Z-4305 dynamic force plate transducers were used. The two plates form part of an instrumented walkway, 13 meters long, incorporating also time-distance monitoring system, and a closed circuit television system. The force plates were positioned one in front of the other with 50% lateral offset. The force information was acquired and stored in files and with the aid of a minicomputer. A hundred and thirty records of twenty-three patients were examined in addition to the special alignment tests conducted with four below knee amputees. Emphasis was placed on the analysis of the antero posterior (A-P) ground reaction force.

All the data were tested for reliability by employing a special consistency test prior to the final filing in the computer. This procedure is based on integration of the force-time characteristics and ensures that the data under consideration are reliable in terms of repeatability of the monitored gait cycles (see Seliktar, 1979).

Results and Analysis

Out of the various parameters of the force characteristics analyzed, the following variables will be discussed:

1. The time ratio between the prosthetic and sound leg stance.

2. The impulse ratio between the prosthetic and sound leg on the vertical aspect.

3. The slope of the force-rise and that of the force-fall on the vertical aspect.

4. Several impulse ratios between the prosthetic and the sound side of the A-P aspect, such as braking vs. braking, pushing vs. pushing, total activity vs. total activity, etc.

5. The fluctuations superimposed on the vertical ground reaction force.

6. Special perturbations on the A-P force curve of the prosthetic side.

1. The time ratio was found consistently high in favor of the sound leg and its variation between individuals was minute.

$$\frac{T\ \text{sound}}{T\ \text{prosthesis}} = 0.91 \pm 0.03$$

This variable was, therefore, ruled out as a possible means of evaluation.

2. The vertical impulse ratio varied significantly between subjects and as a result of realignment of the prosthesis.

Examples of the impulse ratios and their standard deviations, as obtained by averaging the test results on six subjects, are:

Subject 1 - 0.78 ± 0.04
Subject 2 - 0.80 ± 0.01
Subject 3 - 0.93 ± 0.08
Subject 4 - 0.68 ± 0.04
Subject 5 - 0.80 ± 0.04
Subject 6 - 0.82 ± 0.04

The variations between tests on the same subject following adjustments to alignment are also greater than in the time ratios (up to 10%).

This variable, therefore, can serve as activity index and the general conclusion here is that: the greater the impulse ratio index the better the gait performance.

3. The slope of the curve was found an inconsistent factor mainly due to the difficulty in its definition.

4. Impulse ratios on the A-P aspect. There are several relations between the impulses of the A-P forces. The most important concept which was derived from these relations and was reported in an earlier work is the "Gait Consistency Test" (Seliktar, 1979). This test is based on the assumption that locomotion is a cyclic phenomenon. In the steady state of locomotion, the velocities of the body center of gravity at every two corresponding points in consecutive cycles are the same. Since velocities of the C.G. represent the whole body momentum then the impulse: $\int F dt = M(V_2 - V_1)$ between those two points should yield zero. This integration can be employed in order to ensure that the monitored gait cycle is one of a sequence of "identical" cycles, and the validity of the test results can be substantiated by ensuring that a steady-state of locomotion has been monitored.

Each leg exerts a restraining (braking) force at the beginning of the stance phase and a pushing force during the second half. The magnitudes of these impulses are influenced significantly by the performance of the amputee.

Three major factors are of interest:

a. The braking impulse ratios (prosthesis to sound leg).

b. The pushing-impulse ratios (prosthesis to sound leg).

c. Total measured impulse ratio between the prosthetic side and the sound side.

All three impulse ratios vary substantially between individuals, but can also be altered to different extents as a result of training and alignment.

The braking impulse ratio was the one which has had the largest variance in different tests on the same amputee under different alignment conditions of his prosthesis.

The pushing impulse ratio did not vary considerably between tests and between individuals and was, therefore, considered inadequate for quantification of gait disorders.

The total impulse ratio takes into account the sum of the absolute values of impulses on the prosthetic side divided by that of the sound leg. As a result, it compares the extent of use which the amputee makes of his prosthesis and his normal leg. It is in a way also an index of efficacy.

5. The fluctuations on the vertical force curve reflect mainly the stability problems and general interfacial discomfort. Since this force represents the load bearing of the interface, any discomfort or "hesitation" is directly reflected.

6. Perturbations in the A-P force curves seem to be of greater importance especially in reflecting problems arising from the mechanics of the joints and the stump-prosthesis interface. The A-P force changes direction during the stance phase from a restraining (braking) force into a propulsive (pushing) force. As a result of this alternation, its effect on the joints of the leg (prosthetic and sound leg) is a destabilizing one. Any slackness in the joints or the stump-socket interface (which acts as a joint to that effect), produces a jerky toggle action. This toggle action can be observed in around the mid stance portion of the curve in a form of a sinusoidal perturbation. A more severe incongruity may cause a considerable distortion of the curve. Three examples of such perturbations are depicted in Figure (1). In figure 1(a) and 1(b), some improvement can be achieved by realignment. In figure 1(c), alignment will not improve much because the reduced braking and relative poor pushing are a result of a rather complex compensation exerted by hip muscle action. The last one is reminiscent of AK amputee gait.

In both 1(a) and 1(b), there is evidence of interfacial freedom. The dynamic effect of this freedom can be improved to a limited extent by alignment. This can be done by ensuring that the toggle action can be "shifted" to such a location on the curve where the moments about the stump end are minimized.

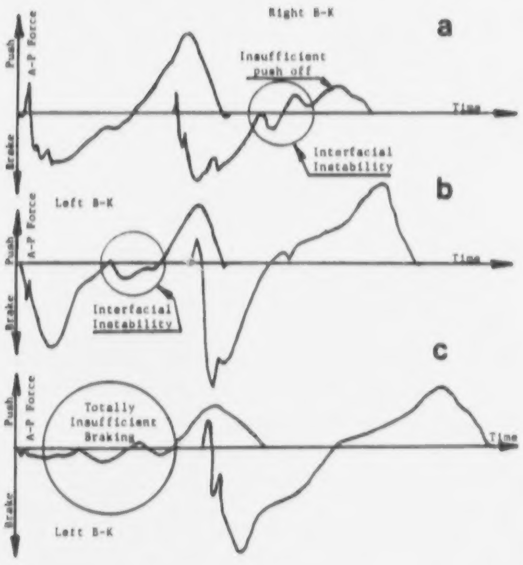

Figure 1. Three different measurements (on three B-K amputees) of the Antero-Posterior (A-P) ground foot forces.

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ACKNOWLEDGEMENT

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A RADIO GONIOMETER FOR USE IN TRAINING ABOVE-KNEE AMPUTEES

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ABSTRACT - A new type of goniometer has been designed for physical therapy use. This device, a local radio-direction-finder, does not require physical linkage of the limbs. Comfortable, small, and lightweight, it is being used to create biofeedback for better gait training of above-knee amputees.

RÉSUMÉ - On a conçu un nouveau type de goniomètre à l'intention des physiothérapeutes. Ce dispositif, en réalité un radiogoniomètre local, n'exige plus que l'on attache les membres. Comfortable, peu encombrant et léger, cet appareil a été utilisé pour générer un signal de bioréaction qui aide grandement à l'apprentissage de la démarche des amputés au-dessus du genoux.

In many physical therapy situations, it is beneficial to have joint angle information. This data can be used to generate biofeedback to accelerate the rehabilitation process. Records of joint movement may help a therapist to evaluate a patient's capabilities and progress.

A new angle measurement device has been built for such clinical applications. It was designed specifically to assist in gait training of above-knee amputees, but is sufficiently general to be useful for a wider range of tasks. This goniometer does not rely on physical linkage between the limb segments under consideration. Its function is best described as a local radio-direction-finder. Small, lightweight packages attach to the adjacent limb segments, connected only by a flexible electrical cable. This instrument is more comfortable to wear than conventional devices, and does not alter the motion being measured.

The device is being used, in combination with a biofeedback system, to assist amputees in achieving adequate hip extension during level walking. Amputee gait is often characterized by poor hip extension, due to hip flexure contraction or lack of confidence in the new prosthesis. Goniometer-derived biofeedback encourages the patient to reach a preset 'acceptable' hip angle threshold.

Figure 1 shows a block diagram of the goniometer. The transmitter is a single transistor sine wave oscillator, operating at 17 kHz. An inductor serves as both the resonating element and the antenna. The receiver consists of two receiving antennas and processing electronics. The two antennas are crossed at right angles, one on top of the other. The amplitude of the received sine waves are Asin(theta) and Acos(theta), where A is a function of the distance between the transmitter and receiver, and theta is the relative angle between transmitter and receiver. First, the signals are amplified. The cosine signal is then full-wave rectified (absolute value only). The sine signal is synchronously rectified, allowing

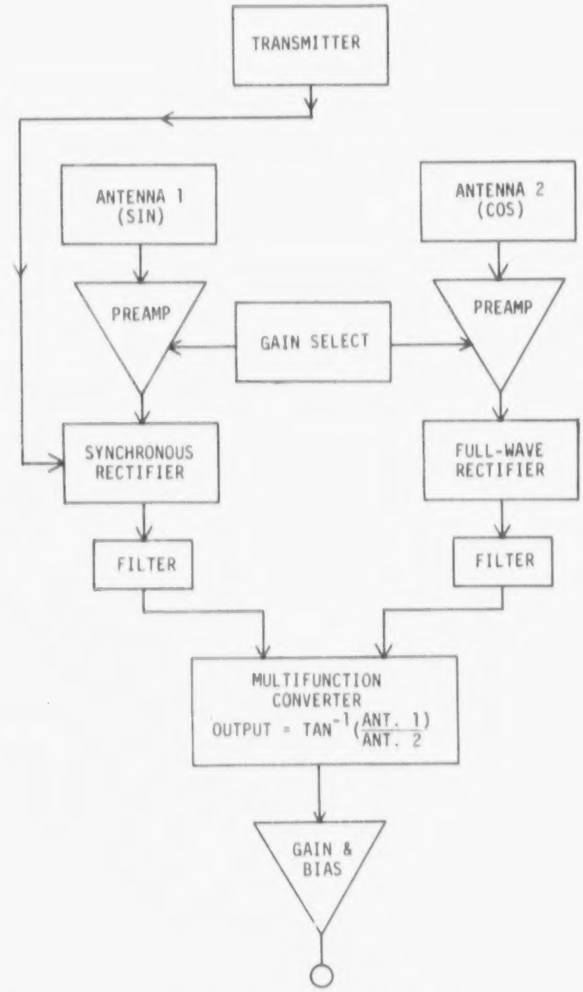

Figure 1 Block Diagram of Radio Goniometer

the mean value to be negative as well as positive. This permits a range of almost 180 degrees. The synchronization is taken from the transmitter output by cable. The rectified sine waves are filtered to extract a DC value. The two signals are divided, producing tan(theta). This eliminates the distance component of the signal. A multifunction converter performs a good approximation of inverse tangent. This signal is then biased and amplified to give the desired output.

Using integrated low power circuitry, this goniometer has been realized in a very compact package. The transmitter is 1.5 inches (3.8 cm.) in diameter and .38 inches (1 cm.) thick, and weighs 1.3 ounces (37 gm.). The receiver is 5.4 inches (13.7 cm.) long by 2.8 inches (7.1 cm.) wide by .5 inch (1.3 cm.) thick, and weighs 4.3 ounces (120 gm.). Both have Velcro patches for easy attachment to a limb or prosthesis. The power requirement for both devices combined is 30 mA at ±5v, or 300 mW. There is a gain switch so that the receiver may operate at different distances from the transmitter. This allows use across a hip which requires a large spacing, as well as use across an elbow and other joints.

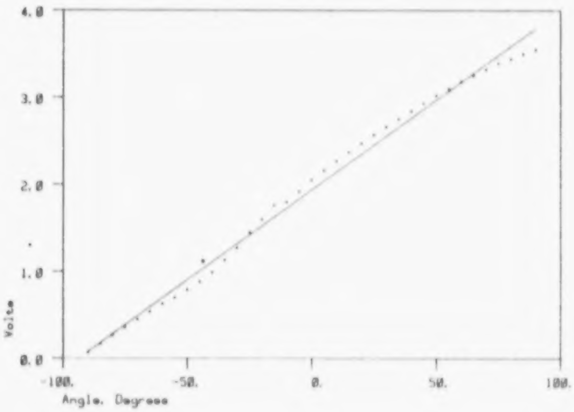

Figure 2 Goniometer Output vs. Hip Angle

There are some limitations to the application of this device. Since it depends on the local magnetic field created by the transmitter for angle information, close metal objects can cause interference. Thus an aluminum crutch or a walker closer than 3" will alter the reading. This problem has been eliminated in amputee training by placing the transmitter on the medial side of the socket. This prevents walking aids from getting close enough to interfere, and the transmitter is small enough that it does not brush against the other leg. There is also a nonlinearity associated with the position of the pivot point. Rotating the transmitter about its own axis produces a different output function than if the center of rotation is between transmitter and receiver, as is the case for joint movement situations. Once the kinematics are determined, however, the output is very repeatable. Repeatability is much more important than absolute angle information in gait training, where the patient is encouraged to reach the same minimum hip angle every gait cycle. Figure 2 shows actual output from the goniometer for a hip angle configuration.

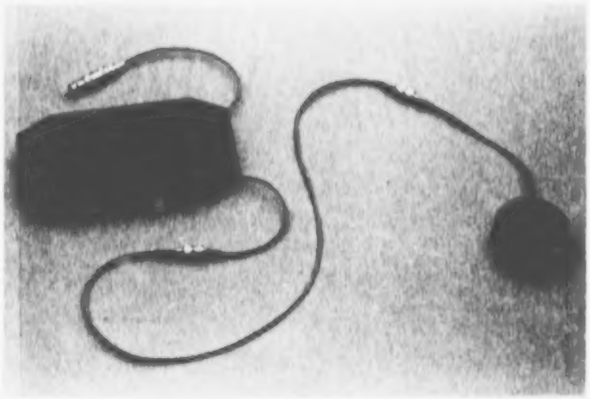

Figure 3 The Radio Goniometer

For the device to be acceptable in a clinical environment, cosmesis is very important. The cases for transmitter and receiver were machined from black acrylic. Visually innocuous Velcro patches were attached, and leatherette applique added to improve appearance (See Figure 3).

Evaluation of this device has begun in a physical therapy clinic (Figure 4). Initial reactions have been favorable. Therapists are finding it helpful in encouraging proper hip extension. A therapist can, without assistance, install the entire system on a patient in less than a minute. Work is continuing, both on the evaluation of the device and on the investigation of new applications.

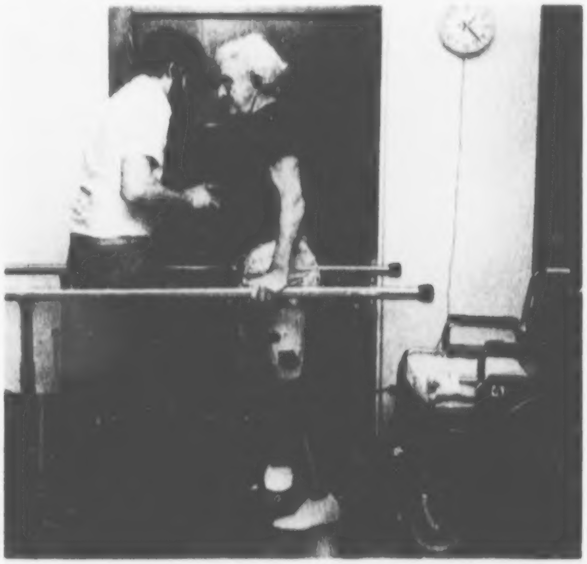

Figure 4 Goniometer and Biofeedback System in use at Massachusetts General Hospital

SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 12

TECHNOLOGY FOR THE HEARING HANDICAPPED I/
TECHNOLOGIE POUR LES MALENTENDANTS I

TELEPHONE COMMUNICATION BETWEEN DEAF AND HEARING PERSONS USING SPEECH-TO-TEXT AND TEXT-TO-SPEECH CONVERSION

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ABSTRACT - SRI has been studying a system that may enable a deaf person and a hearing person to converse over the telephone. The hearing user speaks sentences as isolated words to a large-vocabulary speech recognizer. The output of the recognizer is displayed to the deaf user as a sequence of lists of words that match the input speech. The deaf person interprets this output from contextual information, and then "speaks" by typing to a text-to-speech converter.

RÉSUMÉ - SRI a étudié un système qui permettrait à une personne sourde de converser par téléphone avec une personne pourvue d'une ouïe normale. Cette dernière prononce ses phrases en mots séparés, qui sont détectés par un reconnaisseur de la parole à large vocabulaire. La sortie du reconnaisseur est une série de listes de mots, chaque liste correspondant à chaque mot entré, et présentée à la personne sourde sur un terminal d'ordinateur. La personne sourde interprète alors cette série de listes en choisissant le mot approprié dans chaque liste d'après le contexte, et répond en tapant son message sur le terminal relié à un convertisseur texte-parole.

Background

The research described in this paper is aimed at specifying, demonstrating, and evaluating speech-to-text and text-to-speech systems that permit dialogues between a hearing person and a deaf person over a regular telephone.

Figure 1 is a schematic representation of the desired interaction between the deaf person and the hearing person. Upon being advised of the nature of the interaction, the hearing person is expected to speak with brief pauses between each word. The spoken words are passed to a central computer facility that has both speech recognition and synthesis capabilities. Word recognition is performed by a state-of-the-art isolated word recognizer (IWR), the output of which is displayed on a video display terminal (VDT) at the deaf person's end of the telephone line. As the figure illustrates, the output of the recognizer is a lattice, or series of ranked word lists. The deaf user relies on contextual information to choose a sensible path through this word lattice to understand the speech of the talker.

The deaf person speaks (if intelligible over a telephone) or "speaks" by typing on a keyboard that drives a text-to-speech converter. An efficient keyboard is desirable so the synthesized speech rate is not annoyingly slow.

For such a system to operate successfully, hearing people must be able to speak in isolated words, and deaf people must be able to disambiguate sentence lattices and be able to type efficiently. In addition, the devices in such a system must achieve consistent accuracy for the speech recognizer and immediate intelligibility for the text-to-speech device.

Speech to Text

Perhaps the speech-to-text component of the system is the most crucial for the deaf user, because even those deaf people who can speak for themselves on the telephone cannot hear what is being said to them. Yet, this component is the most difficult to

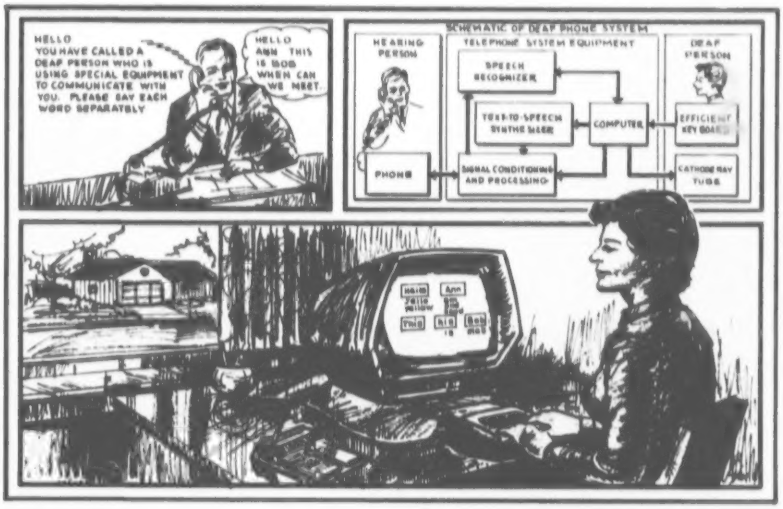
HELLO
YOU HAVE CALLED A DEAF PERSON WHO IS USING SPECIAL EQUIPMENT TO COMMUNICATE WITH YOU. PLEASE SAY EACH WORD SEPARATELY
HELLO ANN THIS IS BOB WHEN CAN WE MEET.
SCHEMATIC OF DEAF PHONE SYSTEM
HEARING PERSON
TELEPHONE SYSTEM EQUIPMENT
DEAF PERSON
SPEECH RECOGNIZER
TEXT-TO-SPEECH SYNTHESIZER
COMPUTER
EFFICIENT KEYBOARD
PHONE
SIGNAL CONDITIONING AND PROCESSING
CATHODE RAY TUBE
Ann

FIGURE 1 OPERATION OF THE DEAF/HEARING TELEPHONE SYSTEM

achieve. Ideally, the system should be speaker independent and the choice of words should be unlimited, but our initial work uses a speaker-dependent recognizer with a lexicon of about 5000 words.

The hearing person must speak with brief pauses between words. To test this ability, we tape recorded five subjects who were required to solve a series of tasks through word-at-a-time instructions and questions. All subjects were able to speak in isolated words without training, and to maintain that speaking style at about 80 words/minute with few errors.

For the speech recognition tasks, we designed a two-stage IWR system for a 5000-word vocabulary. The system preclassifies words phonetically and selects an appropriate vocabulary subset from the total vocabulary. A list of top choices is calculated by the UC Berkeley speaker-dependent recognition system (Murveit, 1983). This system performs very well: The correct word is included 98% of the time among the top four choices, 99% of the time among the top six choices, and 100% of the time among the top 14 choices. Such high performance, however, could not be achieved without speaker dependence.

We spoke standardized reading tests into the recognition system and showed eight subjects (five congenitally deaf and three post-lingually deaf) six-word-deep lattices output from these texts. No punctuation or prosodic information was displayed. We found that those subjects who had good English grammatical skills performed quite well on this task, whereas those we tested who were native speakers of American Sign Language (ASL) with low English skills performed quite poorly. (The subjects whose native language was ASL also had difficulty comprehending English texts even when the texts had not been passed through the speech recognizer.) We are considering several ways to display these lattices to improve their usability for the deaf people. For example, varying the depth of the word lists from six-deep may improve their readability.

Text to Speech

Satisfactory text-to-speech devices are available commercially. We have used the Prose 2000 synthesizer, for which immediate comprehension of speech synthesized from text has been previously reported by Bernstein and Pisoni (1980). Our work in this area is concerned with determining the most efficient keyboard a deaf person can use to drive a text-to-speech converter in order to achieve a relatively normal speaking rate.

We are studying two approaches to the keyboard problem. One approach is based on a stenotype machine similar to those used to record court proceedings and to perform real-time captioning of television programs for the deaf. The other approach uses a standard typewriter keyboard enhanced by a program that predicts the most frequently used words from the sequence of keystrokes.

The stenotype keyboard holds more promise for achieving a normal speaking rate with text-to-speech conversion, because words are typed as syllabic chords rather than individual letters. This system is phonetically based, however, and therefore can be very difficult for the deaf, who often do not have a well-established appreciation for phonetics.

We trained our deaf subjects 4 hours/week for a period of three months to use a stenotype keyboard (with a Baron Data computer translation system). Only those subjects with good speech ability could learn to stenotype, and much greater training is necessary to achieve rates comparable to typewriting. One deaf subject who was especially interested in continuing to learn stenography is concentrating her training only on that task.

The second approach to an efficient keyboard uses a standard (QWERTY) keyboard of a VDT in conjunction with with an "anticipator" program. The user types regular orthography, and the anticipator tries to predict the word as it is being typed by matching the letter string to a dictionary of 250 of the most frequently used words. The dictionary is limited, so that the user can learn all of the abbreviations and is not required to watch the screen. A space character <SP> accepts the current word being anticipated. For example, as shown in Figure 2, as the keystrokes in the left column are typed, the screen would display the anticipated words in the right column.

KEYSTROKES	SCREEN
t	the
h	that
i	this
(SP)	this __
i	this i
s	this is
(SP)	this is __
h	this is he
o	this is how
(SP)	this is how __
y	this is how you
(SP)	this is how you __
c	this is how you can
(SP)	this is how you can __
t	this is how you can the
y	this is how you can ty
p	this is how you can typ
e	this is how you can type
(SP)	this is how you can type __ ...
...	

FIGURE 2 OPERATION OF THE ANTICIPATOR KEYBOARD

Results with deaf subjects have been encouraging. After two months of training at 3 hours/week, several of the deaf people have achieved typing rates using the anticipator greater than their regular typing rates.

Conclusion

Preliminary results are promising. Hearing subjects are able to speak in word-at-a-time fashion; and deaf subjects with good English skills are already able to disambiguate texts output from a large-vocabulary isolated-word recognizer. We continue to try to improve the readability of the display for deaf subjects, although native speakers of ASL may have difficulty reading any form of English text. We also continue to study how well deaf people can generate synthesized speech with a text-to-speech converter. The next major step is to simulate a real-time system and study both the rate and patterns of communication over it.

This research was supported by the National Science Foundation under Grant ECS 8023527.

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DEVELOPMENT OF MICROCOMPUTER-BASED VISIBLE SPEECH AIDS FOR THE HEARING-IMPAIRED

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ABSTRACT - A microcomputer-based system for assisting teachers of the hearing-impaired in fundamental speech instruction has been developed using inexpensive technology. The system provides visual reinforcement for control of phonation, pitch, rhythm and consonant-vowel timing. The flexibility of a computerized instrument for real-time display of basic speech parameters is emphasized.

RÉSUMÉ - Pour aider les enseignants des malentendants, un système par micro-ordinateur a été développe utilisant des technologies peu coûteuses. Ce système renforce visuellement le contrôle de la phonation, l'intonation, le rythme et le rapport temporel entre consonnes et voyelles. On souligne la flexibilité d'un instrument informatisé montrant les paramètres phonétiques fondamentaux en temps réel.

Computers have been used successfully to provide teachers with an indication of certain phonetic behaviours associated with the speech of deaf children [1,2]. In an appropriate speech training program, computerized devices designed to assist the therapist or teacher in the production and control of speech sounds have the potential for increasing success rates, maintaining the child's interest, and objectively gauging progress. Also, the use of the computer for self-instruction has had the reported advantage of increasing the contact time needed for speech training [2].

A number of dedicated instruments have been designed to provide visual feedback of various components of the speech signal as an aid for deaf speech training [2]. These instruments extract and display features such as the fundamental frequency (Fo), amplitude, and simplified spectra. A number of factors have resulted in the lack of general use of these instruments, including their complexity and the lack of adequate documentation. However, the most serious problems are related to the cost of the equipment and the fact that most of the systems are incapable of adapting to a wide variety of teaching techniques and conditions encountered in practice [3].

The objectives of the Visible Speech Aid (VSA) project have been (1) to determine efficient means of representing speech parameters in visual formats and (2) to design and implement an inexpensive and flexible system that displays these parameters, using microcomputer systems that are already available in the public schools. The APPLE II microcomputer was chosen due to its wide availability and for the ease with which custom designed interface boards can be added to the system.

CHOICE OF PARAMETERS

The major problems related to speech production that are encountered by deaf children are the control of phonation (voicing) and the placement or timing of articulation [3]. A population of 19 deaf children ranging from 6-12 years of age were examined to determine their responses to a number of speech parameters represented visually. From these studies it was decided that data acquisition and displays based on the continuous monitoring of Fo and of speech amplitude in two frequency ranges would provide visual feedback appropriate for the recognition and correction of phonatory and pulmonary problems, and would contribute to some correction of articulatory errors.

The Fo display allows training in the areas of pitch control, rhythm and timing, and maintaining modal voice (avoiding harshness and extreme pitch). Using this display for phonatory control for extended durations also provides feedback for the coordination of pulmonary activity. A "computer game" called DUCK WALK has been developed around this parameter to encourage the child to pratice phonatory control. The game displays a previously generated pitch contour on the screen as a reference pattern to be matched by the child's voice.

The amplitude display can be used to demonstrate control of speaking effort and level during the production of longer utterances, while from the split frequency component of the amplitude display it is possible to perform visual segmentation of the vocalic and consonantal portions of utterances. Stops, affricates, fricatives and voiced/voiceless features are differentiated by their temporal characteristics, indicating differences in the manner of production of consonants. However, the actual segment being produced (distinguishable by its place of production as well as its manner) is not shown by the display, and work is continuing in this area.

INTERFACE DESIGN

The hardware design for the VSA involves a peripheral interface board that receives input from an attached microphone. The input signal is amplified and passed through two on-board filters covering the frequency band 70-2300 Hz and above 2300 Hz. The filtered signals are fed to two A/D converters which provide digitized values to the microcomputer's data bus. The output of the lower band is used for display of low-frequency energy and for extraction of Fo while the high band provides information for the display of high-frequency energy. The board is inserted into one of the seven peripheral slots provided on the motherboard.

SOFTWARE DESIGN

Signals picked up by the microphone are converted into the parameters of Fo, low range amplitude and high range amplitude. Using plot routines, the parameters are displayed on the video monitor in distinctive patterns. A split screen approach allows the display of a reference pattern (retrieved from disk storage or produced by the teacher) on the top portion of the screen, to be copied by the child on the bottom display. Visual comparison of the two samples provides feedback to the user regarding the similarity of the two traces and the degree of control the child has of the speech parameter being taught.

The signal processing routines are written in 6502 Assembly Language for speed and are segmented into an amplitude extraction function and an Fo extraction function. In order to take advantage of the flexibility of the microcomputer-based system as opposed to a dedicated hardware implementation, the pitch and amplitude extraction routines and the display software are designed to be readily integrated with high-level software written in BASIC. This allows the experienced BASIC programmer to develop and modify instructional packages that access the available parameters. One such example is the DUCK WALK game mentioned above.

The user-interface routines were written in BASIC and handle menu-oriented communication with the user, storage and retrieval of display patterns and passing parameters to the data acquisition and display routines. The dialogue currently used allows the selection of a pitch, amplitude or rhythm mode, upper or lower screen, a variable time frame of 1, 2 or 4 seconds and the initiation of the display, all with single-key commands. To start the display, an amplitude threshold must be maintained for 60 ms to avoid false triggering from transient noise. A time-out message is also incorporated.

For the amplitude display, the high frequency channel is sampled at 16K/sec and the low frequency channel is sampled at 8K/sec. Sampling occurs in frames of 20 ms duration followed by an analysis and plotting stage of 3 ms. The average amplitude of each frame in the two ranges are plotted above and below a fixed horizontal axis, and processing continues to the next frame. The real-time display shows variations in low and high frequency energy in the form of a histogram on the screen.

A major challenge in the design of the system involved the signal processing requirements for Fo extraction. The relatively limited processing capacity of the 6502 CP necessitated the design of a new time-domain algorithm for real-time Fo extraction. Conventional methods would have required from 2 seconds to several minutes to extract Fo from each 20 ms frame, and would not have permitted a suitable display.

For Fo analysis, the low frequency input is sampled at 7.2K/sec over a 25 ms frame. If the frame is judged to be voiced, the Fo value is obtained by determining the dominant time relationships between maximum amplitude peaks across the frame. Octave shifts are avoided by checking the results of consecutive frames. The value is plotted as a single point on the screen, processing and plotting requiring about 12 ms for each frame. With the time domain on the horizontal axis, the plotted points are joined as they are displayed, producing contours that indicate changes in Fo over time.

FUTURE DEVELOPMENTS

The version of the VSA described here has gone into commercial production with in excess of 40 systems being in use as of December 1983. The development team expects to begin work on an improved model which will include routines for the detection of nasality, vowel quality and a more distinctive representation of consonants. It is also expected that with some modifications to the pitch extraction routine, the system will lend itself to use in the diagnosis of laryngeal disorders.

In the VSA project, the use of simplified spectral displays produced in real time for monitoring and correcting vowel qualities was seen to result in displays that were too complex for visual processing. However, methods of simplifying these displays by reducing them to the level of two formant frequencies are being investigated. An accepted method of estimating vocal tract characteristics is the autocorrelation method of linear predictive coding, which may be used to produce smooth spectral representations and derive formant frequencies. However, the limitations of the 6502 CP will require the incorporation of a peripheral processor on the interface board to achieve this function in real time.

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MULTICHANNEL SYLLABIC COMPRESSION FOR SEVERELY IMPAIRED LISTENERS

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ABSTRACT - Three listeners with severe congenital hearing losses (flat audiograms and dynamic ranges of 20-35 dB) were tested on speech processed by three compression systems and one linear amplification system. The compression systems placed progressively larger amounts of speech energy within the residual dynamic range. The comparison linear system was defined by adjusting six octave-wide bands of speech to comfortable levels. Intelligibility results were speaker dependent, with compression consistently providing better performance for one speaker, linear amplification for the other. Averaged over speakers, however, no listener derived a net advantage from any of the compression systems.

Introduction

Although syllabic compression has not generally improved speech reception for moderately impaired listeners when compared to carefully chosen linear amplification, it may be useful for listeners with severe hearing loss (e.g. Villchur, 1973, Braida et al., 1982). At present there is no method for determining optimum compression characteristics for a given listener: not only must a large number of parameters be specified, but also there are few analytic studies to guide the choice of parameter values. In this study, perceptual experiments were conducted with severely impaired listeners to define appropriate compression characteristics in terms of the properties of the hearing loss and speech materials, and to evaluate compression relative to carefully chosen linear amplification.

Subjects

Two individuals with severe congenital bilateral sensorineural hearing loss and relatively constant dynamic range over the frequency range 125-8000 Hz participated in this study. The listner with the most severe loss (a residual dynamic range of only 20 dB over the 125-8000 Hz range) was tested only in the better ear. The other listener was tested separately in both ears, which had dynamic ranges of 20 and 35 dB.

System Characteristics

For listeners with severely limited dynamic ranges, there is a trade-off in the selection of compression parameters. If high compression thresholds or small compression ratios are used, only peak speech levels can be made audible and intelligibility will be low because many speech elements are inaudible. If wide input ranges are compressed, speech cues conveyed by amplitude differences will be degraded. To evaluate this trade-off, we studied three compression systems whose compression thresholds were chosen to place 25%, 50%, and 90% of the short-term amplitude distribution of speech in each of 16 frequency bands (roughly 1/3 octave, 100-10000 Hz) above the listener's threshold. Compression ratios were selected individually on the basis of listening tests. As expected, listeners generally selected increasing compression ratios for the 25%, 50%, and 90% systems. Under the listening conditions chosen, peak (1%) speech levels were well below discomfort levels measured with pulsed tones.

Comparison linear amplification systems were derived in accordance with OMCL criteria (Lippmann et al., 1978) by having listeners adjust 6 octave-wide bands of speech to comfortable levels. The frequency-gain characteristics chosen tended to raise fixed percentages of speech levels above threshold in each frequency band. For the least impaired ear, roughly 50% of the speech range was above threshold in each band; for the more severely impaired ears, only 10-25% of the levels were audible with linear amplification.

Intelligibility Tests

The speech test materials consisted of 800 CVC nonsense syllables spoken by one male and one female talker. All utterances were normalized to the same rms level before processing. Identification tests were administered after 8000 practice trials and consisted of one presentation of each item per speaker per system to each of the three listeners tested.

None of the compression systems tested was superior to the OMCL linear system in terms of overall performance. For the listener with the largest dynamic range, the 50% and 90% compression systems and the OMCL linear system were roughly equivalent (80% phonemes correct) and superior to the 25% compression system by roughly 5 percentage points. For the two more impaired listeners the 25%, 50%, and OMCL systems were roughly equivalent (65% phonemes correct) and superior to the 90% system by roughly 8 percentage points. For these two listeners compression improved the intelligibility of final consonants, but degraded reception of vowels and initial consonants.

It should be noted that the results were highly speaker dependent, with differences across speakers often larger than those across systems. Compression consistently improved the intelligibility of the female speaker but degraded that of the male. Averaged over speakers, however, no listener derived a net advantage from any of the compression systems.

Even when comparable levels of performance were achieved, phonetic feature reception was different for compression and linear amplification. For consonants, compression generally improved manner distinctions but degraded place distinctions within a manner category. Vowel identification was also degraded by the 90% system for the two more severely impaired listeners. These confusions are consistent with the spectral flattening introduced by the use of independent compression in the different frequency bands.

Conclusions

The compression systems tested were at best equivalent to the linear system in terms of overall performance. In general, systems employing moderate compression ratios and compression regions spanning the top 25 to 50% of the short-term input speech range were superior to those which compressed 90% of the input range.

High levels of performance were generally achieved with linear amplification for the less severely impaired listener, for speech materials that were presented at a constant input level. Thus well chosen linear amplification, coupled with some form of automatic volume control to reduce long-term level variations, may be more beneficial than syllabic compression for listeners with flat losses and dynamic ranges of 35 dB or more. By contrast, the performance scores for the listeners with more severely restricted dynamic ranges, were generally quite low even under the best presentation conditions.

It is clear that a simple mapping of the input speech range into the residual auditory area is inadequate: the transformation must also preserve important acoustic differences between speech sounds. A more appropriate compression strategy would reduce overall level variations while maintaining, or perhaps emphasizing, relevant acoustic cues. The relatively good performance achieved with 25% of the speech range above threshold suggests that preservation of spectral peaks may be more important than the audibility of lower amplitude speech levels. Future work should explore systems which employ interchannel control algorithms in order to preserve relevant short-term features while reducing overall level variations.

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Footnote

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ELECTROACOUSTIC CHARACTERISTICS OF FM AND INFRARED DEVICES APPLICABLE TO IMPAIRED EARS

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ABSTRACT. In-situ electroacoustic expertises of FM auditory trainers, Infrared systems intended for impaired ears and FM systems using the conventional FM band were carried out. FM systems were found to provide more amplification. However, infrared and FM systems using the conventional band more efficiently amplified frequencies above 1 kHz.

RÉSUMÉ. Des aides auditives à transmission MF, des systèmes à infrarouge ainsi que des émetteurs MF sur bande conventionnelle sont expertisés sur KEMAR. On trouve un meilleur potentiel d'amplification pour les systèmes MF. Cependant, les systèmes à infra-rouge et le MF sur bande conventionnelle reproduisent plus efficacement les fréquences au-delà du 1 KHz.

FM and infrared carriers were proposed in recent years to help the hard-of-hearing understand remote speech. FM auditory trainers were introduced first. They were intended for the classroom situation where hearing-impaired children experienced problems listening to the teacher's voice because of the distance factor (Matkin and Olsen, 1973). More recently, infrared devices were made available to assist the hard-of-hearing while listening to some remote audio signal like TV sound track (Sennheiser, 1982). Also, for the last few years, we have been testing transmitter microphones using the conventional 88 to 108 MHz band in conjunction with portable FM radios or "Walkman"-type instruments as an alternative way to amplify remote audio signals. To date, however, very little is known of the electroacoustic characteristics of such devices when considered as prosthetic devices: FM auditory trainers got most attention in this respect but still, information remains sketchy (Picard, in prep.). Accordingly, the present reports on frequency response and gain characteristics of various FM and infrared systems intended for hearing-impaired listeners. Devices broadcasting on the conventional FM band are also included in order to estimate their suitability as auditory prosthesis.

FM Auditory Trainers

"In-situ" frequency response and gain characteristic of three commercial FM auditory trainers are shown in figure 1. Informations were obtained on KEMAR. Instruments were used in the FM mode solely. They were adjusted for maximum bandwidth and maximum power output. HF-gain ranged from 41 to 58 dB. In all cases, there was a severe reduction of amplification above 1 KHz.

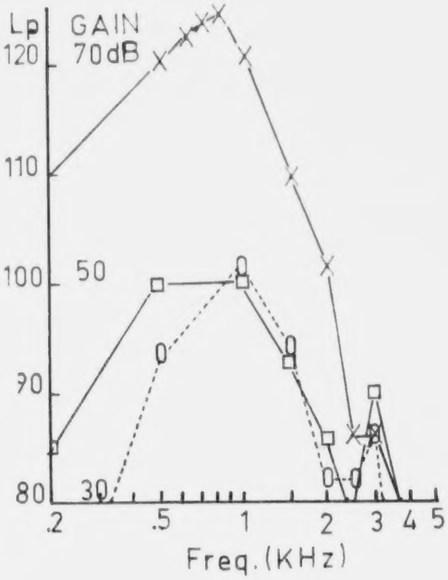

Figure 1. In-situ response curve of three FM auditory trainers

Infrared devices

An infrared system used with three different earphones was tested the same way FM auditory trainers were. Results are shown in figure 2. HF-gain ranged from 14.6 to 17.3 dB, a dramatic reduction when compaired to values typical of FM auditory trainers. In addition, there is no effective gain below 1.5 kHz, which is just contrary to the way FM auditory trainers behave.

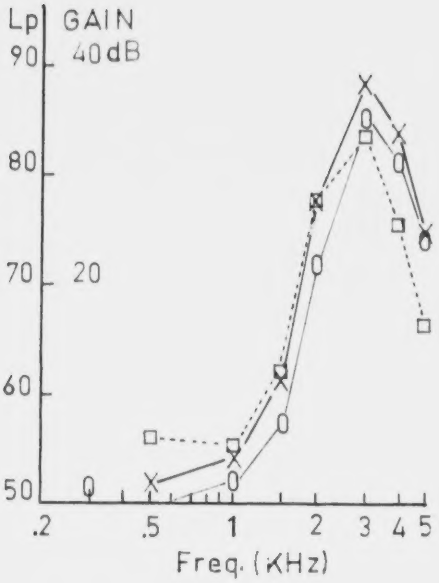

Figure 2. In-situ response curve of an infrared system used with three different earphones

Devices using the conventional FM band

A transmitter microphone broadcasting in the conventional FM band was used in conjunction with three types of receivers: one portable FM radio connected to audiometric earphones and two "Walkman"-type devices. All systems were tested the same way FM auditory trainers were. Figure 3 illustrates the results. HF-gain range from 26.6 to 29 dB for the "Walkman"-type receivers. The portable FM radio showed an impressive HF-gain of 63.6 dB. In all cases, the effective bandwidth was large, ranging from 560 to 4600 Hz for the radio fitted with audiometric earphones and from 200 to 4600 Hz for the other devices.

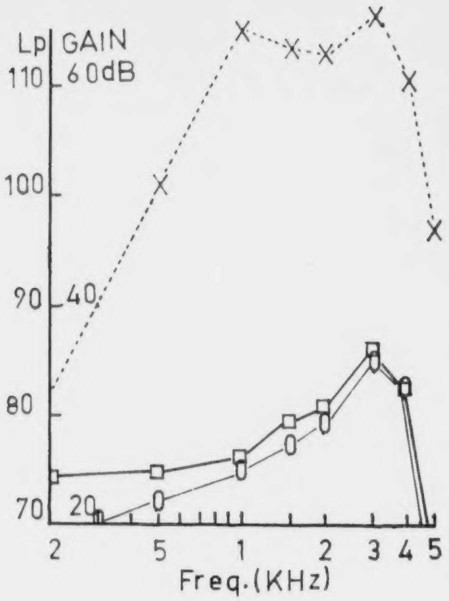

Figure 3. In-situ response curve of an FM equipment used in conjunction with three conventional radios (X=portable radio; 0 and □="Walkman"-type receiver)

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A COMPUTER BASED SYSTEM FOR MODIFYING DEAF SPEAKERS' PHONATORY BEHAVIOR

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ABSTRACT - This paper describes a computer based system for modifying aspects of deaf speakers' phonatory behavior. Discussed are system and software development, as well as assessment and training procedures used to modify vocal fundamental frequency characteristics. Preliminary training results will also be presented.

RÉSUMÉ - Cette communication décrit un système informatisé pour modifier des aspects du comportement phonatoire des orateurs sourds. On discute de la mise au point de systèmes et de logiciels, ainsi que des méthodes d'évaluation et de formation utilisées pour modifier les caractéristiques de la fréquence fondamentale de la voix. On présente également les résultats préliminaires de certains travaux de formation.

Deaf individuals often experience considerable difficulty learning to control and coordinate respiration, phonation and articulation/resonance for production of intelligible speech. While research shows that abnormalities in speech breathing and phonatory control often characterize the speech of deaf individuals, little in the way of improved techniques for ameliorating these problems exists.

The research reported here explores the development and use of a computer based system for assessing and modifying the phonatory behavior of deaf individuals. Among the phonatory errors characterizing the speech of deaf speakers are deficits in fundamental frequency (F0) control, voice quality, consonant voicing and voice initiation and termination. Because voice fundamental frequency (F0) is the most recognized and dominant parameter of phonation, it was selected as the first parameter for investigation. The goals of the first project were: (1) Development of a computer based system that can extract, analyze and display F0; (2) Development, implementation and evaluation of assessment protocols; and (3) Development, implementation and evaluation of training protocols.

THE SYSTEM

The system developed at Gallaudet for assessing and modifying F0 is part of a larger system for modification of various phonatory parameters. The general phonatory modification system is comprised of:

1. Transducers for obtaining acoustic (a microphone), aerodynamic (a pneumotachograph) and physiological (an electroglottograph) correlates of laryngeal behavior, as well as a transducer for detecting respiratory behavior;
2. Specially designed signal processors for extracting parameters such as F0, acoustic intensity, etc.;
3. A DEC 11/34A digital computer system for signal processing, data acquisition, recording, retrieval and graphic display control;
4. Visual display units for displaying analog, digitized, or processed signals of phonatory monitoring during training and for data acquisition and analysis to document subject's status and improvement.

The transducer selected for real-time extraction and display of voice F0 is the electroglottograph (EGG), which detects the degree of vocal fold contact. While F0 could be obtained from other available signals (for example, the acoustic signal), the EGG has the major advantage of being free from vocal tract resonances. This device has been shown to be effective for obtaining measures of F0 by others (Fourcin and Abberton, 1971).

The EGG signal is then submitted to a custom made signal processing system for F0 extraction. This system, described by Hasegawa, et al. (1983), provides the computer with a measure of the cycle-by-cycle F0 period through a parallel interface. The F0 period information is then converted to frequency (through a look up table) which is subsequently used for real-time display of a particular parameter, while the original F0 period is recorded in a data file for further analysis. The F0 period resolution of the entire system is approximately 1 Hz.

Three types of real-time parameter displays can be generated on the video monitor screen. The first display is an F0 histogram, indicating the frequency of occurrence of discrete F0 ranging between 30 Hz and 400 Hz. The second display provides a fundamental frequency contour, while the third display depicts F0 level without the time scale. Each of these displays has been developed with specific assessment of training objectives in mind.

ASSESSMENT

An assessment protocol has been developed which provides detailed information about a speaker's F0 control. The protocol is used to: (1) Determine appropriate therapy goals for a particular subject; (2) Describe F0 characteristics before and after training; and (3) Develop normative scales of F0 control to measure and describe effects of training.

To obtain a comprehensive description of a given speaker's control and use of F0 it's necessary to collect data during a number of different speaking tasks. The three major types of speech samples obtained are: (1) connected speech (spontaneous and read), (2) production of syntactically homogeneous sentences (e.g., declarative sentences, yes/no questions, etc.), and (3) production of sustained vowels at different F0 levels. Computerized data acquisition, reduction and analysis yields a number of descriptive statistics concerning a speaker's F0 control during each speaking task. Among the statistics obtained are: (1) A histogram of cycle-to-cycle distribution of F0 during each task; (2) Measures of mean, median and mode of that distribution; (3) Measures of distribution variance and skewness; (4) Estimates of the speaker's F0 range; (5) Summary of the amount and direction of cycle-to-cycle changes in F0.

Data has also been obtained for a group of normal-hearing speakers. By comparing a deaf speaker's performance to this normal "template", it is possible to determine a speaker's specific F0 control difficulties, and subsequently to develop training objectives that are appropriate for that individual.

TRAINING

A rehabilitation sequence has been developed which is consistent with current training procedures for F0 modification (Ling, 1976) and that utilizes various features/displays of the Gallaudet system. The sequence reflects a hierarchical modularized arrangement of tasks, with initial training directed toward nonlinguistic activities (target and pattern matching using sustained vowels) while later training emphasizes linguistic tasks (for example, production of terminal rising intonation patterns to signal a question).

Training was initiated with three subjects with the primary purpose being to determine the value of the system for modifying phonatory behavior, and also to refine the instructional sequence, reinforcement schema, record keeping, etc. Preliminary training results showed that the system is useful for modifying certain aspects of deaf speakers' F0 control, and that it could facilitate development of correct intonation patterns (Mahshie, et al., 1983).

Based on these initial results, additional subjects are currently being instructed with visual feedback in order to modify the following F0 characteristics: (1) Use of an expanded range of F0, (2) Use of a lower or higher average F0, (3) Use of appropriate terminal rising or falling intonation patterns to signal questions vs. statements. Thus far three subjects have each received from 12 to 17 training sessions. While each showed varying degrees of change in their phonatory behavior, all three subjects demonstrated some improved ability to control F0 for the tasks taught during training. For example, Table 1 gives the percentage of monosyllabic words intended as questions that were perceived as produced with a rising intonation pattern. Column labeled "before" gives percent correct before training, the next column gives percent correct after training without visual feedback, while the last column gives percent correct after training with visual feedback.

TABLE 1

	Before (Vis. Fdbk.)	After (No Vis. Fdbk.)	After (Vis. Fdbk.)
S24	10%	35%	50%
S22	0%	55%	55%
S21	0%	10%	0%

It should be noted, however, that these improvements were not always observed in more connected discourse, suggesting that additional training is needed.

THE FUTURE

It has been suggested that disruptions in one aspect of phonatory behavior (e.g., voice quality) can influence other phonatory parameters (e.g., F0) (Metz, et al., 1982). Accordingly, work is currently underway to initiate modification of other aspects of deaf speakers' phonatory behavior, including atypical respiratory patterns, aberrant voice quality, and inaccurate consonant voicing. It is anticipated that development of a comprehensive phonatory modification system and instructional strategies will lead to more affective, efficient speech habilitation.

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A DIRECT METHOD FOR IMPROVING BREATH CONTROL BY THE DEAF

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ABSTRACT - Many visual or tactile systems (1,2,3,4) have been developed for helping the deaf to overcome their numerous speech problems, but their practical usefulness often falls sadly short of their technical sophistication. This paper presents the first results obtained with a new device allowing direct external control over subjects' exhaled airstream.

RÉSUMÉ - Dans ce travail on présente un nouvel dispositif de contrôle de l'air expiré pendant la phonation des enfants qui souffrent des sordités congénitaux. D'après les résultats obtenus on dirait que l'usage de l'appareil présenté, constitue une bonne voie pour améliorer la qualité phonologique des premiers mots articulés de ces enfants.

INTRODUCTION

The notoriously defective speech of people with impaired hearing owes its irregularities to the failure of the auditory feedback path. In the case of those born deaf, the very acquisition of speech must overcome the same problem, typical effects of which are weak phonation, wrongly timed breathing (e.g. intake between syllables) and lack of intonation. Phonetically, many of these features are due to faulty breath control rather than incorrect articulation. The device described below tackles this problem directly by enabling the teacher to control the exhaled airstream of the pupil, thus providing him with experience of correct breathing patterns. We are hopeful that this direct experience may act as an effective springboard from which deaf children can go on to control their breathing by themselves.

THE AIRSTREAM CONTROLLER

The device (fig. 1) consists of a face mask (A) connected to a sensitive microphone (B) and a short open tube (C). The latter is pierced by a needle (D) connected via 4 electrovalves to an external source of compressed air. The mask should be big enough as not to impede the facial movements of speech. The microphone is connected via an A/D converter to a microcomputer which at this present preliminary stage serves only to process the voice signal for analytical and display purposes, but which in future will also carry out higher functions to assist the teacher in controlling the pupil's speech.

The principle of the device is simple. When the pupil exhales weakly and the teacher wishes to increase the vocal air supply, the electrovalves stopping the needle D are opened and a jet of air is injected under pressure into tube C. Since the system is open, the resulting Venturi effect sucks air from the pupil's lungs and forces him to exhale more strongly. The air jet is naturally not so strong as for its effects to cause discomfort or impede the pupil's breathing in normally, and its intensity can be controlled by varying the number of electrovalves opened.

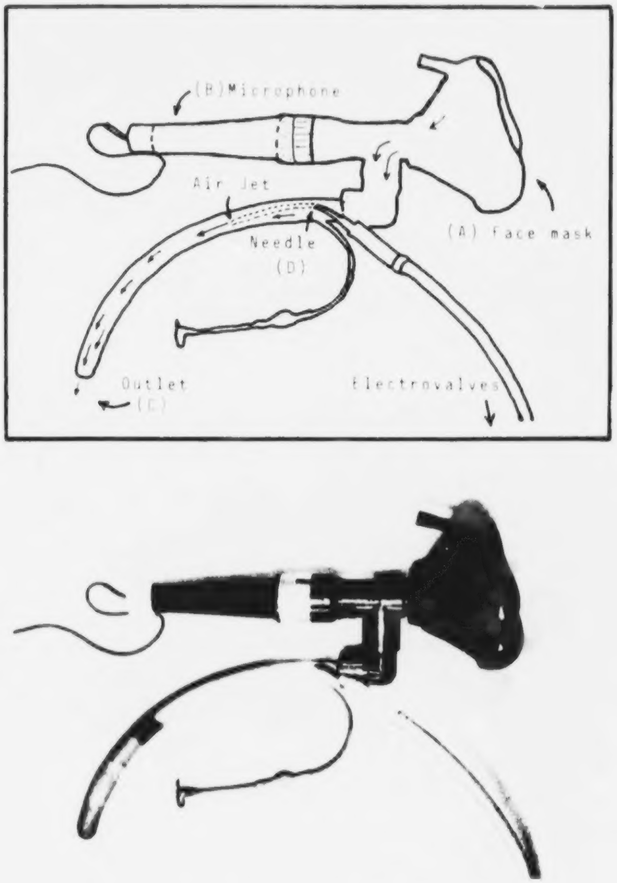

Fig. 1. The aistream controller

THE MICROCOMPUTER SYSTEM

The system at present in use (fig. 2) consists of an HP-9825T data acquisition system with 64 Kbytes of memory connected to an HP-3495A scanner, and HP-9871A printer and HP-9872A plotter. The use of

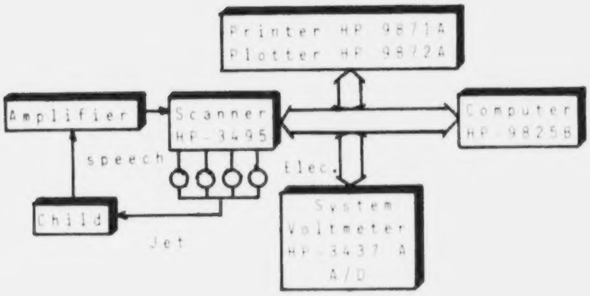

Fig. 2. Electrovalve control system

a dedicated microprocessor system may be considered later. A sampling frequency of 6,5 KHz was found to be sufficient for our purposes.

DATA PROCESSING

The sampled voice signal is plotted directly in the time domain, and segmented in 20 ms blocks and passed through a Hamming window for spectral analysis using 12 linear prediction parameters.

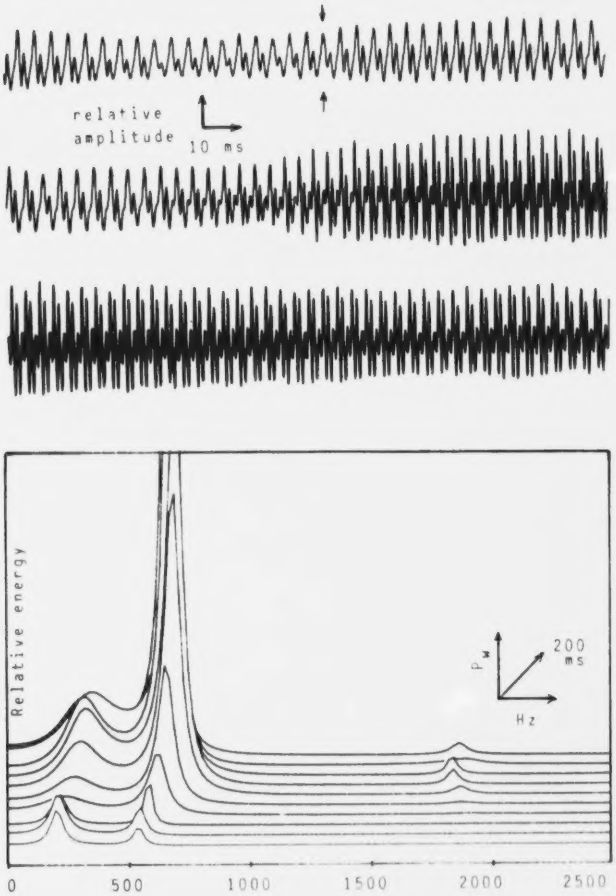

Fig. 3. Voice signal of a Spanish |o|. The arrow marks the opening of the electrovalves

Although this technique does not retain the fine structure associated with the source of excitation, it is very efficient in identifying formant frequencies.

RESULTS

Fig. 3 shows the results of applying the device to the pronunciation of a Spanish |o|. Both the low energy and the poor formant structure of the vowel as initially uttered are probably due to the weakly exhaled airstream. Some 200 ms after the electrovalves are opened (arrowed), the voice signal becomes not only stronger but also much richer in formants (fig. 3). An unlooked-for result is that there is usually also a slight shift towards higher frequencies, which may later be corrected. During the delay period the subject's own involuntary breath control system seems to resist the changes forced on it, and the response to the applied air jet is at times initially oscillatory, but no discomfort is felt. Subjects are aware of the enhancement of their breath expulsion and soon learn to "swin with the tide" and collaborate with the applied air jet.

CONCLUSION

The results described above demonstrate the efficacy of the device for inducing enhaced breath expulsion. Before it can be properly tested on deaf children, however, its effects on different types of speech deficiency must be further investigated and its use integrated in a comprehensive training programme, for which we invite the collaboration of speech therapists. Only then can an evaluation be made of its effectiveness as regards the ultimate aim of helping the deaf to learn to control their breathing unaided.

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LE MICRO-ORDINATEUR COMME FACTEUR POUVANT SUSCITER DES INTERACTIONS SOCIALES ENTRE ENFANTS HANDICAPÉS AUDITIFS ET ENFANTS DE CLASSE RÉGULIÈRE

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RÉSUMÉ - Ce document s'avère être un plan de projet de recherche concernant l'analyse de l'impact social de l'emploi du micro-ordinateur en milieu scolaire régulier vivant une expérience d'intégration avec une clientèle d'enfants handicapés auditifs.

ABSTRACT - This document contains a research proposal plan for analysing the social impact of the use of microcomputers in a regular school which is involved in an experiment to integrate a group of hearing-impaired children.

Le projet de recherche s'effectuera à l'école Côte du Nord à Hull. C'est une école élémentaire à l'intérieur de laquelle sont intégrées trois classes d'enfants handicapés auditifs de niveau maternelle, premier et deuxième cycle. La situation que présentait cette école s'avérait propice au genre de recherche que nous nous proposons.

Les interrogations premières qui ont motivé notre recherche et auxquelles nous tenterons de répondre se formulent ainsi:

1. Est-ce que le micro-ordinateur est un intérêt commun aux deux types de clientèle?
2. Est-ce qu'en présence du micro-ordinateur les deux clientèles échangeront entre elles?
3. Est-ce qu'il y aura un transfert des interactions sociales en dehors des sessions expérimentales déterminées?

Le projet repose sur un modèle de recherche de type descriptif et qualitatif il sera basé sur l'observation systématique et l'analyse des faits.

Voici les démarches effectuées:

- un échantillon d'enfants hand. aud. et d'enfants de classe régulière a été sélectionné en vertu de critères précis (choix, nombre, âge, niveau académique)
- les conditions environnementales ont été déterminées (lieu, fréquence des sessions, équipement)
- les moyens pour effectuer la cueillette des données et les analyses de résultats sont finalisés (grilles d'observation, guide d'entrevue, format de témoignages)
- la procédure des sessions expérimentales et le personnel impliqué sont déterminés

Le projet de recherche débutera à la fin du mois de janvier 1984 pour une période de 16 semaines. Il se terminera en mai 84. Nous croyons qu'un tel projet s'avère nécessaire pour ouvrir d'autres avenues de recherche en ce domaine. La contribution possible de cette recherche c'est qu'elle permettra de mettre en lumière les répercussions de la nouvelle technologie en ce qui concerne l'intégration sociale des enfants handicapés auditifs. On sera en voie de se questionner si le micro-ordinateur deviendra l'instrument prévilégié de l'avenir, celui qui assumerait les différences de potentiel intellectuel, les différences de rythme d'apprentissage des enfants. Devant le micro-ordinateur ou le visuel prime sur l'audition dans quelle mesure leur handicap existe-t-il? est-il encore une entrave?

Les rapports de la recherche seront présentés à la conférence advenant le cas ou elle serait sélectionnée.

Les coups de financement de ce projet sont assumés par la Commission Scolaire Régionale de l'Outaouais (personnel et équipement)

Le projet est parrainé par un des membres du personnel de la Faculté d'Education de l'Université d'Ottawa en la personne de M. D. Lévesque Ph.D.

EXPERIMENTS WITH A WEARABLE TACTILE PITCH DISPLAY

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ABSTRACT - A wearable device for the tactile, spatial display of voice fundamental frequency is described. Such a device has potential value as an aid to speech instruction. It can also function as a prosthetic aid to speech production and perception. Experiments with normal and hearing-impaired subjects show the detection of small changes of fundamental frequency and discrimination among intonation contours.

RÉSUMÉ - Ici on décrit un appareil mettable pour le déploiement tangible et spatial de la fréquence de la voix. Un tel appareil peut assister dans l'instruction de la parole. Il peut aussi être un aide prosthetique pour la production et la perception de la parole. Les expériences avec les sujets normaux et sourds montrent la découverte de changements petits de la fréquence, et la distinction parmi les contours d'intonation.

There have been many attempts to solve the problems of deafness with sensory aids that transform the acoustic patterns of speech into patterns that can be perceived visually or auditorily. (Levitt, Pickett and Houde, 1980). In most cases, the use of such devices has been restricted to the provision of temporary input and feedback during speech instruction. Researchers have long recognized the need, however, for the kind of continuity that can only be provided with a wearable device. Such a device can still aid in speech training. In addition it can function as a prosthesis, facilitating the control of motor speech behaviors and supplementing speechreading as a means of speech perception.

The device to be described provides feedback and input about voice fundamental frequency. It is intended to aid in the production and perception of intonation contours, voicing, and rhythm. It utilizes the tactile sense and represents fundamental frequency as the locus of vibrational stimulation.

TACTILE PITCH DISPLAY. (SEE FIG. 1.)

The pitch display accepts input from an acoustic microphone, or from an accelerometer attached to the throat. The input signal is low-pass filtered to extract the fundamental frequency which is then converted to a square wave. A pitch period meter times the first half-cycle of each square wave and uses the information to select one of eight output channels which is then activated for the second half-cycle. The output transducer array consists of eight miniature solenoids with a separation of 6 mm. The output channels are equally separated on a logarithmic scale of frequency. The electronic package is worn on a belt and includes three rechargable 9 volt batteries. It should be noted that the solenoid vibrations are synchronous with fundamental voice frequency. Thus the display provides both temporal and spatial information. (See Boothroyd, 1983, for a more detailed description.)

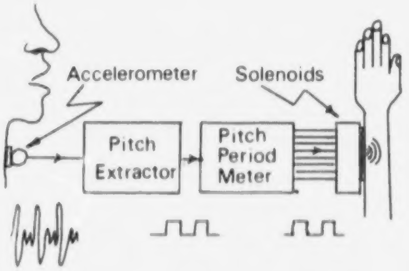

Figure 1. Block diagram of pitch display

EXPERIMENT #1

The main goal of the first experiment was to determine the acuity for pitch falls presented via the pitch display to the hand and forearm. A secondary goal was to compare the spatial-temporal display with a single channel, temporal-only display consisting of a bone conduction oscillator. Stimuli consisted of square wave bursts with a 200 msec fixed frequency section followed by a 200 msec linear frequency fall. Just noticeable falls were established using an adaptive procedure and a 3 interval forced choice paradigm. Three stimulus locations were used: the thenar eminence, the medial surface of the hand, and the medial surface of the forearm. Five normally hearing subjects were tested.

All five subjects were immediately able to detect a single channel pitch fall, in all three stimulus locations, using the multichannel display. (This represents an average pitch fall of .09 octaves if the eight channels are configured to cover a range of 1.5 octaves.) In contrast, only two of the five subjects were able to establish consistent thresholds during 2 1/2 hours training with the single channel display on the thenar eminence. The just noticeable falls of these subjects were .21 and .29 octaves from a starting frequency of 300 Hz, and .32 and .90 octaves from a starting frequency of 150 Hz.

These data were taken as evidence that the hand and forearm have sufficient acuity to detect movements of vibratory patterns involving a change of at least one channel of the eight channel transducer array. They also indicate that a temporal-spatial display of pitch provides more immediately interpretable information than does a temporal-only display.

EXPERIMENT #2

The goal of the second experiment was to determine whether subjects could discriminate between widely contrasting intonation contours derived from natural speech and presented via the multichannel display. Two locations were used: the medial surface of the hand and the medial surface of the forearm. Three tests were used. The first required subjects to decide whether a sentence was spoken on a monotone as with natural intonation. The second required them to decide whether a word or phrase was spoken with a pitch fall or a pitch rise. The third required them to locate the stressed word in a three word phrase. Eight normally hearing subjects participated. Each was tested on two occasions.

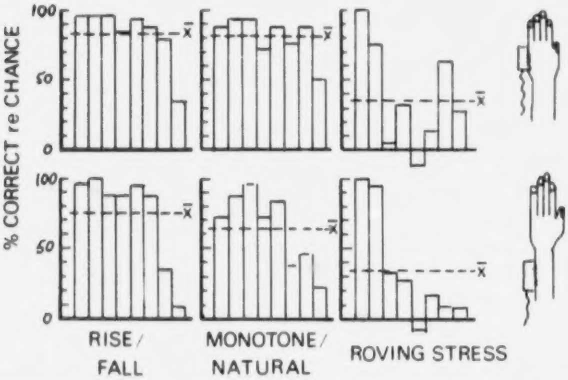

Figure 2. Performance of eight normally hearing subjects on three tasks requiring discrimination between intonation contours presented tactually at two locations.

The results are shown in Figure 2. Analysis of variance confirmed that forearm placement was poorer than hand placement and that the roving stress task was more difficult than the other two. Nevertheless there were subjects who were able to score at or close to 100% on all three tasks.

EXPERIMENT #3

The third experiment involved a 17 year old male with a profound (105 dB), congenital, hearing loss of genetic origin. He was orally educated and wore hearing aids consistently. The goal was to compare his intonation discrimination using hearing aids alone, with that obtained using hearing aids plus the multichannel display. The medial surface of the forearm was used for tactile presentation, and discrimination was tested with the three tasks just described.

The results are shown in Figure 3. It will be seen that, with hearing aids alone, performance was at chance levels on the monotone/natural and the rising/falling tasks, but significantly better than chance on the roving stress task. With the addition of the multichannel pitch display, performance was significantly better than chance on all three tasks.

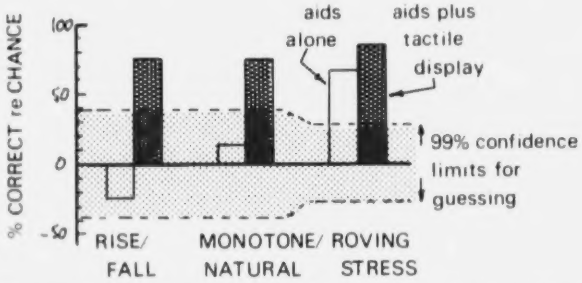

Figure 3. Performance of hearing-impaired subject on three tasks of intonation discrimination.

CONCLUSIONS

These data provide evidence that the tactile pitch display, as presently designed, meets two necessary conditions, -it permits the detection of small changes of fundamental frequency, and it allows discrimination among contrasted intonation contours. Moreover, it can meet these conditions for forearm placement, -a practical consideration if the aid is not to interfere unduly with the activities of daily living. These are by no means sufficient conditions however. Research is in progress to determine whether long term use of the device will result in improved control over the parameters of voicing, rhythm, and intonation. Additional studies will measure the potential value of the device as a supplement to lipreading.

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ACKNOWLEDGEMENTS

Nancy Springer collected the psychophysical data. Joseph Isaacs and Cecil Redmond assembled the pitch display. The work was supported by NIH grant #NS17764.

TEXT OUTPUT IMPROVEMENT IN SPEECH CAPTIONER PERFORMANCE

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ABSTRACT - Language-oriented assistive devices, such as speech captioners, aim to produce orthographically correct transcripts at conversational rates. Up to now, those speeds have been attained only in systems producing inconsistently correct orthography. A new interface suggests ways of achieving desired speeds without sacrificing quality output.

RÉSUMÉ - Jusqu'à maintenant la traduction des codes produits par un clavier pour la transcription du langage parlé a été atteinte avec des erreurs orthographiques périodiques. Une nouvelle interface suggère une façon d'atteindre cette vitesse du langage parlé sans sacrifier la qualité du résultat.

INTRODUCTION

Since 1978, a few deaf individuals in Britain have been using personal speech captioners in their daily business; since October 1982, deaf Americans have been able to view real-time live closed captioning of selected television programs; since late spring of 1983, a small group of deaf individuals in California has been training to use a stenotype-driven speech synthesizer as a speech prosthesis in telephone conversations. These are three examples of current work to incorporate modern microprocessor technology and language processing capabilities into a variety of assistive devices.

THE SPEED/SPELLING ISSUE

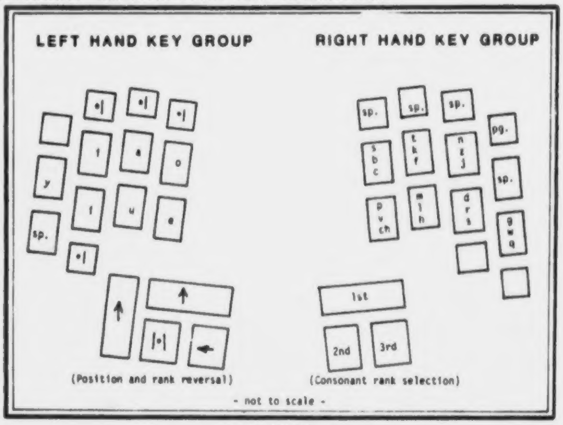
Stenotyped chord input.

In order to produce text output at conversational rates, the devices mentioned above all employ some traditional chord keyboard input interface, such as stenotype or palantype. On these, keys are not struck individually, but rather together, as the keys in a piano chord. The result is that each stenotyped chord contains information equivalent to several typewriter keystrokes, and trained operators can take verbatim transcripts of speech at conversational rates. The speed advantages of stenotyped and palantyped input are counterbalanced by a disadvantage: the machines do not record properly spelled text, but rather lists of phonetic syllables, abbreviations and punctuation marks. Automating the process of producing clean text output has not been simple: the resulting transcripts contain periodic gibberish that must be edited out. Until breakthroughs occur in the field of artificial intelligence -- and this may well be some time in the offing -- it is doubtful that these transcription problems can be solved. For a speech captioner, such problems are serious: there is no "later editing" on a speech captioner -- the captions are produced correctly either the first time or not at all. To complicate matters, precisely because of the operations which cluster syllables together into polysyllabic words, the automatic translation errors can misinterpret not just single syllables, but lists of several items, creating periodic "domains of nonsense", within which nothing -- not syntax, nor lexicon, nor general sense -- pertains to what precedes or follows (in one demonstration, "editors" became "he had torques", for example). Such domains can make cognitive processing of the sentence doubly difficult, not only because of the meaningful elements which they remove, but also because of uncertainty which they raise as to their extent: determining where they end can be especially difficult at first reading.

Letter-based chord input.

Recently, a Bulgarian-developed device called the 'stenokey' has demonstrated the feasibility of an alternative approach, one which combines the greater efficiency of the stenotype-style chord keyboard input with the explicit operator output control of the qwerty (= standard typewriter) keyboard. It does this by accepting input chords that represent lists of letters, spaces and punctuation marks, together with instructions on how those items are to be positioned on the page relative to one another. The task to be carried out by the processor is thus straightforward and explicit (which processors do well): spatially positioning tokens according to supplied instructions. The operator is required to carry out all the "pre-processing", such as breaking the words into appropriate letter strings, and striking the chords representing the letter / positioning information. These are demanding tasks, but ones which people have demonstrated the ability to master. The division of labor between man and machine seems well designed to achieve the desired goal, the production of clean text at high rates. In the hands of trained operators, stenokey performs well. In one of the earliest reports of the machine to appear in an American publication, an eyewitness to a demonstration writes "The machine prints in syllables, and it can be operated at 310 syllables a minute" (equated with 221 words per minute in a later calculation) "and the text will come out in normal form (... that is, properly typed with correct spelling, punctuation, etc.)". It can also be used at higher recording rates, if abbreviations are acceptable: in various European speed competitions, it has been operated for eight minutes at a maximum rate of 450 syllables per minutes (ca. 321 words per minute), capturing thereby either first and second place for the past several years at Intersteno meetings.

STENOKEY DESCRIPTION AND OPERATION



KEYBOARD

Description.

Stenokey was on display for several days in August 1983 at the National Shorthand Reporters Association Annual Convention in Washington, D.C., during which time the autor had an opportunity to familiarize himself with its operation. In important respects, the device is very unlike its nearest competitors, stenotype and palantype. It makes a serious attempt at incorporating elements of good ergonomic design. For example, it features two distinct keypads -- one for each hand -- located a comfortable distance apart and slanted inward from the parallel, as the hands are when coming together. The keys themselves are located on a gentle arc, corresponding to the position of the fingertips in typing position. Thought has been given to a rational partition of the cognitive and manipulative workloads. The left-hand keypad records only the vowel letters ('a', 'e', 'i', 'o', 'u', 'y'), interword spaces and some positioning information. The right-hand keypad records the consonants, punctuation marks, spaces, and some additional formatting information, thereby placing the greater manipulative workload on the right hand, which is stronger in most people. The thumbs record information about positioning the letters struck.

A comparison was made between qwerty, stenotype and stenokey in producing common English words, and some numerical indices of operation extracted therefrom. These give a sense of the relative keying workload demands made by each input device. In producing the hundred most common words of English, a qwerty operator must use 443 finger-strokes to depress 443 keys (including the concluding space 'terminator' on each word). To produce an standard stenotyped transcript of the same word list, the operator would use 275 finger-strokes to depress 341 keys in 102 chords. For this corpus, then, in practice each stenotyped chordstroke captures the information equivalent to 4.34 qwerty keystrokes; each finger-stroke depresses an average of 1.24 stenotype keys; and there is on average 1.02 chords per word. On the stenokey device, the operator uses 516 finger-strokes to depress in 653 keys in 160 chords. This means that, in practice, each stenokeyed chordstroke captures the information equivalent to 2.77 qwerty keystrokes; each finger-stroke depresses an average of 1.27 keys; and there is on average 1.60 chords per word. In other words, stenokey here requires some 57% more chordstrokes per word than stenotype overall; but this is still only 63% the number of keystrokes required to record the same corpus on a standard typewriter, though the output in both latter instances is proper orthographic text. The number of fingers per chordstroke (2.70 for stenotype, 3.22 for stenokey) and keys depressed per finger (1.24 for stenotype, 1.27 for stenokey) are roughly comparable on the two chord machines.

Conclusion

Although its design and performance are not beyond criticism, stenokey suggests promising directions for improving the performance of speech captioners and other assistive devices which require rapid and accurate input of language information to processors. Studies of the principles and their applications are underway at our Rehabilitation R&D Center.

Acknowledgements

This work has been supported by the Veterans Administration's Rehabilitation Research and Development Center, Palo Alto, California. Trip arrangements to see the stenokey device in Washington, D.C. were made by Baron Data, Inc. of San Leandro, California.

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A CUSTOM INTEGRATED CIRCUIT IMPLEMENTATION OF A TACTILE VOCODER

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ABSTRACT - This paper describes the design of a custom integrated circuit implementation of a tactile vocoder. This device, which presents speech and environmental sounds as patterns of vibration on the skin has evolved over the past ten years from a laboratory research device towards a miniaturized, wearable sensory aid for the profoundly deaf.

RÉSUMÉ - Cette communication décrit la conception d'un vocodeur tactile adapté à circuits intégrés. Le dispositif transforme la parole et les bruits environnementaux en vibrations perçues par la peau. Ce dispositif qui, il y a dix ans, était un appareil de recherche en laboratoire est maintenant devenu un appareil d'assistance sensorielle portatif pour les sujets atteints d'une surdité profonde.

INTRODUCTION

Work on the development of a tactile vocoder for the profoundly deaf began at Queen's University in the early 70's. The first functional prototype was built from discrete semiconductors, occupied an equipment rack approximately 5 feet high, and consisted of more than 33 printed circuit cards. In 1981, a second, portable prototype was built using 60 medium scale integrated circuits and several hundred discrete components. The size of the device was reduced to about 1 cu. ft. and the weight was reduced to about 2 kg.

Although these devices were useful for demonstrating the feasibility of using the tactile sense as a substitute channel for auditory information, (Scilley, 1980; Mason, Scilley & Frost, 1981; Brooks & Frost, 1983), they were impractical as aids other than in a laboratory or training environment because of their size and power consumption. The next stage in development therefore, was to take advantage of the recent advances in custom integrated circuit design in order to produce a wearable device functionally equivalent to the successful prototypes.

SYSTEM DESIGN

A block diagram of a single channel of the present tactile vocoder is given in figure 1. The incoming auditory signal is first separated into 16, 1/3 octave segments with the centre frequencies of the channels ranging from 200 to 8000 Hertz. The energy in each channel is then detected and compressed using a logarithmic amplifier. The resulting signals are used to control the amplitude of a 100 Hz carrier which is fed to a linear array of solenoids spaced 3 cm apart on the ventromedial forearm. Thus, the frequency of the auditory signal is translated into place of stimulation on the forearm and sound energy in a given bandwidth is translated into amplitude of vibration of a particular solenoid. The prototype system uses 16 parallel channels and only analog signal processing.

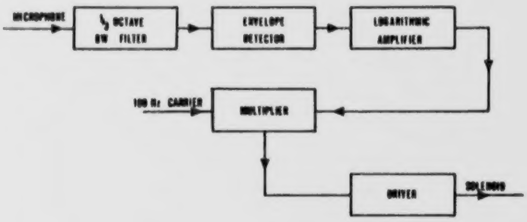

Figure 1

INTEGRATED CIRCUIT DESIGN

The miniaturized version of the device uses a combination of analog and digital processing. It is made up of two VLSI integrated circuits plus a limited number of discrete components and a set of drivers for the solenoids. The first VLSI circuit, a commercially available chip (ASA-16, Interstate Electronics), performs the signal filtering into 16, 1/3 octave channels, detection , and time division multiplexing. The companion custom chip is designed to digitize the signals, perform the logarithmic compression and generate the signals necessary to supply the solenoid drivers. This chip contains a single A/D converter, logarithmic converter, and demultiplexer, and sixteen identical output stages

- one for each channel. Figure 2 is a block diagram of the custom integrated circuit.

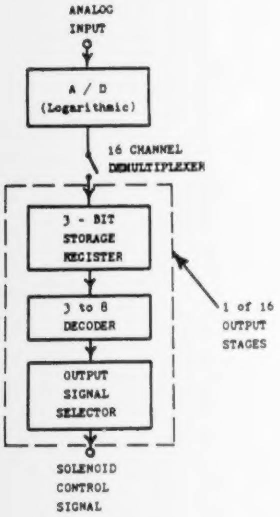

Figure 2

The analog to digital conversion is performed by comparing the analog input signal to a series of reference voltages that are logarithmically related to each other. This comparison is done by 7 parallel comparators. Each comparator output is a logical one if the analog input signal exceeds the reference voltage; otherwise, it is a logical zero. The outputs of the comparators are then combined by a priority encoder to produce a 3 bit, logarithmic representation of the analog input signal in each channel. This 3 bit representation is transferred, by means of a 3 bit, 16 channel demultiplexer, to one of sixteen output stages. In the output stage, the 3 bit word is stored in a dynamic memory register until the next time that particular channel is sampled. From the register, the encoded word is decoded into eight signals, only one of which is high, depending on the value of the stored word. This high signal is used to select the appropriate output waveform from a series of reference waveforms. These waveforms are 100 Hz. square waves of different amplitudes. The amplitude of the waveform selected is proportional to the magnitude of the 3 bit word which in turn is proportional to the logarithm of the value of the analog input for that channel.

The complete integrated circuit contains close to 2000 transistors and measures 2492 microns by 5604 microns. It has been designed using the simplified design rules for Nothern Telecom's double-poly, nMOS process. The design was submitted to Nothern Telecom for fabrication in September 1983.

Acknowledgements

This work has been supported by Health and Welfare Canada and The Natural Sciences and Engineering Research Council.

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NEW AMPLITUDE COMPRESSION TECHNIQUES

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ABSTRACT - Two new multiband compression techniques for reducing the short term level variation of speech are presented. "Principal Component Compression", is directed at the problem of spectral flattening which tends to degrade certain speech cues. Unlike conventional multiband compressors, which process different bands independently, principal component compressors process each band on the basis of signal levels in all bands so as to compress independently the principal components of the short-term spectrum (e.g. overall level and spectral tilt). "Multiband Peak Clipping", is concerned with achieving extreme reductions in level variation. In this technique, signals are analyzed into a relatively small number of bands, each of which is infinitely peak clipped and refiltered to attenuate out-of-band distortion components.

Introduction

Previous research on multiband syllabic amplitude compression has generally employed two distinct approaches for reducing the short-term level variation of speech signals (Braida et al., 1979). In the "compression amplifier" approach, compression is achieved on a band-by-band basis by measuring the short-term band level and attenuating the band signal progressively (using a variable-gain linear amplifier) as the measured band level increases. In the "instantaneous nonlinearity" approach, a nonlinear compressive function of the waveform in each band is determined and the resulting signal is filtered to attenuate out-of-band distortion components. Each of these approaches is subject to limitations likely to restrict the usefulness of compression. For example, compression amplifiers can only achieve small reductions in the dynamic variation of signals in a given band (De Gennaro et al., 1981). Furthermore, independent multiband compression tends to flatten short-term spectra, degrading speech cues based on spectral detail. On the other hand, compressors which employ instantaneous nonlinearities introduce substantial waveform distortion associated with residual harmonic and intermodulation components.

Principal Component Compression

The tendency of multiband compressors to reduce spectral fine structure can be overcome by utilizing the correlation of speech level variations in different frequency bands, compressing each band as a function of the levels in all the bands. Principal component analysis of speech band levels derives a set of uncorrelated signals as a linear combination of the correlated band levels. The principal components of short-term speech spectra represent independently varying aspects of spectral shape. Thus, compressing principal components allows non-interacting features of spectral shape to be modified. The first and second principal components of the short-term speech spectrum correspond roughly to overall level and spectral tilt, whereas the higher order components represent more detailed aspects of the spectrum (Zahorian and Rothenberg, 1981). Since, the first two components account for about 80% of the band level variation, but contribute very little detail to shape of the short-term spectrum, they are logical candidates for compression.

To evaluate the effectiveness of Principal Component Compression relative to both wideband and conventional multiband compression, we made short-term band-level measurements of running speech (e.g. Dunn and White, 1940, but made separately for vowels and consonants using a 16-channel critical band filter bank). Measurements of unprocessed speech indicate that the range of vowel levels is relatively narrow at low frequencies, widening to roughly 30 dB at 1 kHz, whereas the range of consonant levels is wider, about 35 dB across the frequency range.

A single-channel wideband compressor, which does not alter the shape of the short-term spectrum, is capable of reducing the range of consonant level variation to about 20 dB below 1 kHz, but above 3 kHz neither consonant nor vowel level variation is compressed. By contrast, a 16-band Principal Component system can significanty reduce both consonant and vowel level variations across the frequency range. This reduction can also be achieved by a conventional multiband system which compresses bands independently. However, measurements of the short-term spectra of fricative consonants processed by the two systems indicates that spectral shape differences are preserved far better by the Principal Component system.

Multiband Peak Clipping

When speech is transmitted over a channel with limited dynamic range, intelligibility is improved by peak clipping. This appears to result from the high peak factor of speech (14 dB) and the large contribution to intelligibility made by relatively weak (consonant) segments. The effects of peak-clippers on speech signals are not well understood. While peak-clipping distorts the speech waveform, spectral analysis (Blachman, 1964) and empirical observation indicate that if the input spectral envelope has a maximum at a given frequency, the output spectrum will have a maximum near that frequency. While subsidiary spectral peaks may be altered by clipping, the largest peak is generally preserved, and even sharpened in some circumstances. The short-term spectral envelope of speech is typically characterized by a small number of peaks (particularly the formants of voiced speech). Thus it should be possible to reduce the short-term level variations while preserving the location of spectral peaks, by peak-clipping non-overlapping frequency bands.

We have studied a multiband compressor in which speech is analyzed into three bands corresponding roughly to the three lowest formant regions (0.2-0.9, 0.9-2.8, and 2.8-6.0 kHz) prior to infinite clipping. Postfiltering is applied to each clipped ouptut to attenuate out-of-band distortion components, and the resulting signals are added to form the signal presented to the listener.

The system was evaluated with PB-50 word lists by two persons with normal hearing who listened with noise added to processed speech to provide a rough simulation of a hearing loss. Peak speech levels were restricted to roughly 25 dB SL at all frequencies. Under these conditions, word scores were 4% with amplified speech and 36% with clipped speech. Tests using Harvard sentences produced key-word scores of 17% with amplified speech and 98% for clipped speech.

In a second study, which attempted to simulate communication in a noise background, multi-talker babble was added to speech prior to processing, and no hearing impairment was simulated. In the absence of noise the processing degraded word scores from 100% to roughly 80%. In the presence of babble, the intelligibility of processed speech is comparable to that of unprocessed speech in 6 dB more intense noise. These results do not corroborate those of Thomas and Ravindran (1974) who found that high-pass filtering and clipping improved the intelligibility of noisy speech. Additional tests in which their experimental conditions were duplicated (with the exception that the overall level was lower) failed to replicate their result, one of the few successful reports of intelligibility enhancement for speech corrupted by noise.

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A MICROCOMPUTER-BASED SYSTEM PROVIDING GRAPHIC FEEDBACK IN REAL TIME TO THE HEARING IMPAIRED[*]

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ABSTRACT - This paper describes the development of a system which produces immediate graphic representation on a two dimensional plane for presenting to the user an indication of his/her approximation to the correct pronunciation of vowels in certain monosyllabic words.

RÉSUMÉ - Cette communication décrit le développement d'un système qui produit immédiatement une répresentation graphique sur un plan de deux dimensions pour présenter à l'usager une indication de son approximation à la correcte prononciation des voyelles dans certains mots monosyllabiques.

This paper reports a microcomputer-based system designed to assist the user in approximating the correct pronunciation of certain targetted utterances by means of visual feedback represented as graphic abstractions of the linguistically relevant portion of the acoustic signal generated by the speaker's voice and analyzed by the computerized system. An earlier stage of this project proved the feasibility of having a microcomputer function as a sound spectrograph and was reported by Park et al. (1983). The current system concentrates on teaching correct vowel pronunciation in monosyllabic words. The system is able to operate in real time, because the automated recognition of vowels is relatively simple, as opposed to consonants, whose recognition this project is not currently pursuing. Also, it is with accuracy of vowel production that many people with hearing difficulties have trouble, as tongue configuration for vowel production is not as easy to observe visually, nor to imitate, as is the case with consonants, especially bilabial stops such as [p] and [b].

Upon viewing the acoustic spectra of vowel cross sections, taken at a given point in time, it is found that the relative amplitudes of the various harmonics are distributed in such a way as to show prominent peaks at certain frequencies. Clusters of harmonics displaying prominent amplitudes are called formants. The formants observable in speech spectrography are customarily identified by number, according to ascending frequency levels: F_1, F_2, F_3... The fundamental frequency of the speaker's voice is often referred to as F_0. For purposes of vowel recognition, F_1 and F_2 will generally convey sufficient information. The enhanced amplitude of the harmonics, members of these formants, and the atenuated amplitude of harmonics elsewhere along the spectrum, results from constructive and destructive interference caused by modifications to the shape of the oral cavity which result as the tongue assumes different configurations during the production of vowels. Table 1 displays the formant frequency levels of the vowels in the words beet, bat, and boot, as spoken by a male adult whose voice has a fundamental frequency of approximately 120 Hz.

	F_1	F_2
[i] beet	250 Hz	2500 Hz
[æ] bat	720	1600
[u] boot	300	840

Table 1 Formant Frequencies

An inventory of the fourteen vowels generally accepted as constituting the set of vowels for North American English shows that each vowel displays its own unique combination of frequencies for F_1 and F_2. Formant frequencies applicable to a given vowel will vary if the speakers in question do not share the same fundamental frequency and do not have similar size and shape of oral cavities. This project has overcome this problem by storing reference templates prepared from the speech samples of several individuals of different sex and age, thus providing the user with speech targets he/she can safely emulate, as the template being used has the parameters of a speaker whose fundamental frequency and size and shape of air oolumn roughly match those of the user.

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The data in Table 1 become more interesting when they are reformatted as Figure 1, where F_1 is plotted against F_2, as x and y axes. The way in which phonemic space is depicted by this plot has been of interest to linguists for some time, and has served as a bridge between acoustic phonetics and articulatory phonetics, and, more importantly, it has provided this project with a necessary paradigm.

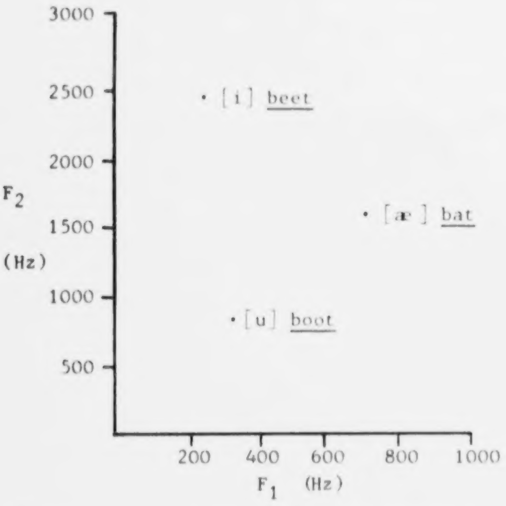

Figure 1 First vs. Second Formants

The plots in Figure 1 easily translate into a lesson for a student who has already learned to articulate the consonants [b] and [t], as a result of observation and imitation, but needs improvement in the pronunciation of vowels. A possible lesson would present the word beet as a target, spelled and/or in picture form, in that sector of the screen corresponding to the coordinates for the vowel [i]. The student could then be asked to pronounce the word beet. The response would produce a blinking cursor somewhere on the screen, indicating how close to the target the response actually was. As long as the user produces a vowel sound, the system will acknowledge and provide feedback concerning the user's approximation to the correct pronunciation. Repeated attempts should steer the student closer and closer to the desired target, as pronunciation improves. "Wrong" responses can be turned into opportunity items in cases where the response coincides with the screen location of a competing word such as boot by spelling the word boot and/or providing a picture, thus giving desired positive reenforcement.

In order to have the system operate in real time, it was found advantageous to be selective about which data were to be considered for sampling and processing. The simplicity of the acoustic features of the vowel allows recognition of a vowel based on just one time slice. The decision as to when to sample an utterance is made by monitoring a channel where signal frequencies above 750 Hz and below 200 Hz have been filtered out. The remaining frequency range coincides with the upper and lower limits of first formant frequencies for all vowels. Once the signal amplitude within this frequency range exceeds a predetermined threshold, a routine proceeds to rapidly collect samples to place on one page of computer memory. A separate routine is invoked to perform a fast Fourier transform (FFT) on the data, using the conventional decimation-in-time Cooley Tukey algorithm, which proves to be much faster than the usual discrete Fourier transforms. A test-and-hold routine identifies the first two formants and their respective frequencies from the spectrographic section obtained by the FFT. The plot of these two formants against each other on the screen then serves as feedback to the user.

Further economies in processing time were obtained by writing software in Pascal instead of BASIC, and using 8088 Assembler to read the input. While a co-processor is not being used at the present time, its implementation may be necessary and desireable for applications beyond that presented here.

The hardware currently used in the project consists of an IBM PC microcomputer with second disk drive, an analog/digital converter, an amplifier, a pre-amplifier, and a microphone. It is noteworthy that other microcomputers already on the market are applicable to the system under discussion.

While the rehabilitative potential for this system is obvious, there is also possible applicability to the area of language instruction. A wide base of users is to be desired, as this would encourage further research and development, thus producing spin-off benefits for all concerned. As microcomputer use gains wider acceptance and prices become more affordable, more and more approaches will become feasible. Fifth generation computers, many times faster than what we have today, should raise the expectations of the hearing impaired in their quest for improving their communication skills.

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TEMPORARY THRESHOLD SHIFT DUE TO HEARING AID USE

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ABSTRACT. An investigation of TTS resulting from amplification is conducted with six hearing aid users. Critical times for a significant TTS to take place as a result of exposure to amplified speech are compaired at 1, 2 and 3 KHz. Results indicate vulnerability to TTS for most subjects (4/6).

RÉSUMÉ. L'étude s'intéresse à la fatigue auditive consécutive au recours a l'amplification. Les durées critiques nécessaires à l'acquisition d'une telle fatigue sont examinées auprès de six usagers aux fréquences de 1, 2 et 3 kHz. On note une fatigue auditive chez quatre des six sujets examinés.

The development and widespread use of modern hearing aids have led to increased concern over the potential deterioration in hearing sensitivity associated with the use of amplification. To date, however, research in this direction is far from being concluding: results obtained have been mixed, with some studies supporting the existence of overamplification and others failing to reach a similar conclusion (1,2). The present study was undertaken to explore possible TTS resulting from the use of hearing aids by moderate to moderately-severe hearing-impaired listeners. This population was selected because of indications to the effect that as the loss of sensitivity increases, TTS decreases (2). Six hearing aid users with average hearing levels ranging from 40 to 80 dB were exposed to amplified speech babble. Average level of the signal delivered to the ear was set at 110 dB (that is, 65 dB for the speech signal plus a constant 45 dB gain provided by an aid). Because of the fluctuating nature of speech signals, however, maximum output of the instrument was set at 123 dB. After a 24 hr rest period, subjects were exposed for increasing periods of time (2.5, 5, 10, 20, 40 and 80 min.) up to the point a significant TTS was observed. Testing was resumed at that point. However, additional sessions were introduced, beginning with the exposure time necessary to induce a significant TTS at the previous stage. Subjects were discharged when TTS coincide for a given exposure over two consecutive sessions. Results indicate strong relationships between critical times (that is, the time required to reach a significant TTS) and pre-exposure hearing losses: correlations of .97, .87 and .9 were found at 1, 2 and 3 KHz, respectively. Single-case studies revealed different subjects' behaviours: no critical time could be determined for the two subjects with the largest pre-exposure losses. Conversely, the one with the smallest pre-exposure loss of sensitivity showed short critical times for all three frequencies that is, greater vulnerability to TTS. Two subjects with losses not so extreme as the ones mentioned before showed critical times to be shortest at 2 kHz when compaired to the ones at 1 and 3 KHz. Similarly, critical times obtained at 3 KHz were shortest than the ones at 1 kHz. Results are interpreted as new evidence that TTS due to hearing aid use decreases as pre-exposure loss increases. The presence of TTS after short exposure times in not so extreme listening situations also warns against minimizing the risks of overamplification.

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IMPROVED PERCEPTION BY THE HEARING-IMPAIRED FOR SPEECH PROCESSED WITH ENHANCED ACOUSTIC CUES

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ABSTRACT - For hearing-impaired listeners, voicing perception of S, Z, F, and V was examined for syllables without versus with enhancements of these consonants' voicing cues. Compared to performance for the unenhanced syllables, most listeners showed large improvements in consonant voicing perception for the syllables with enhanced cues.

RÉSUMÉ - Pour les auditeurs malentendants, la perception de la sonorisation des consonnes S, Z, F et V a été étudiée avec et sans amplification de ces consonnes. La plupart des auditeurs ont montré une grande amélioration dans la perception de la sonorisation des consonnes pour les syllabes amplifiées.

Computer technology may soon be available to accomplish real-time modifications of the acoustic patterns of speech. Acoustic modifications of speech could be used for rehabilitation of persons with various handicaps of speech recognition or perception. Prior to rehabilitative use, however, it will first be necessary to discover the types of speech modifications that best facilitate speech perception.

For hearing-impaired and deaf persons we recently studied the effects on speech perception of various alterations of acoustic segments in speech. This paper presents preliminary results of two such studies, one examining a particular type of temporal modification, and the other examining certain spectral modifications of speech.

In the studies, some of the speech stimuli that were experimentally modified were the syllables BASS, BAZZ, BAFF, and BAV. These are rhyming syllables that differ only for their final consonants: S, Z, F, and V. Using these consonants we examined a particular perceptual feature called the "voicing distinction". When a listener can distinguish voicing for these consonants, it means only that (s)he distinguishes the "S" versus the "Z", and the "F" versus the "V". The voicing distinction is highly important in differentiating among consonants of all languages.

Such consonant voicing distinctions are often difficult or impossible for persons with severe hearing impairments and for most with profound impairments. Our prior work has shown which speech acoustic segments or cues are more salient for hearing-impaired persons in their perception of consonant voicing distinctions (Revoile *et al.*, 1982 and 1983). We found that some hearing-impaired persons depend mostly on certain temporal cues, for distinguishing consonant voicing. For example, the durations of vowels preceding final consonants are important temporal cues for consonant voicing perception by such hearing-impaired persons. Other hearing-impaired persons rely on temporal and spectral cues. Some spectral cues of importance are the frequency characteristics of the burst or friction when certain consonants are produced in speech.

Based on these findings we reasoned that particular temporal and spectral speech acoustic-cues might be exaggerated or enhanced in various ways to increase their salience, and thus improve improve perception of consonant voicing distinctions for hearing-impaired persons with reduced perception.

Methods. The enhancement of the temporal and spectral acoustic cues were carried out on different utterances of each of the test syllables: BASS, BAZZ, BAFF, BAV. These utterances had been spoken by a female, and subsequently converted from analog to digital form (16.67 Hz sampling rate) for acoustical measurements, and processing of the cue enhancements. The acoustical measurements included certain duration and spectral measurements of the vowel and consonant segments of each utterance.

For the study on temporal cue enhancements, the vowels preceding the final S, Z, F, or Z, were altered in duration. In the syllables with final "Z" or "V", the preceding vowels were lengthened; the vowels preceding "F" and "S" were shortened in the syllables.

For the study on spectral cue enhancements, the final consonants' friction noises were altered spectrally. The "F" and "S" frictions were low-pass filtered, and then intensified. The "V" and "Z" frictions were replaced by a segment that occurred at the end of the vowel in each utterance. These segments contained some consonant friction noise. The segments were low-pass filtered, and also high-pass filtered to reduce the contribution of the vowel. Finally, the segments were lengthened and intensified. For all of the syllables, the consonants' friction noises were altered without modification to the preceding vowels or initial "B"s.

In both studies Gallaudet College undergraduate students participated as listeners (total N = 46). About one-half of the listeners had profound losses (≥90 dB Hearing Level for .5, 1, 2 kHz threshold average). The other listeners had either severe or moderate losses.

The listeners' perception for the consonants was tested using syllable identification trials. Among the trials, each test utterance was presented singly. The listener was required to choose which of the four syllables: BASS, BAZZ, BAFF, BAV, was presented. No feedback of response accuracy was provided.

Blocks of trials were tested first for the syllables without cue alterations. Subsequently, the syllables with enhanced cues were tested. Generally, the syllables without versus with the enhanced cues were tested in separate listening sessions. Most sessions also included some syllable-discrimination procedures, which facilitated the listeners' perceptual training of the consonant voicing distinctions. The listening sessions occurred twice weekly for more than two months, over which repeated tests of consonant perception were administered.

Results. In both experiments the majority of listeners showed considerable performance improvements for the consonants in syllables with enhanced cues, compared to consonant perception for the unenhanced syllables. For the study of vowel duration enhancements, consonant voicing perception is summarized in Table 1 for 15 of the listeners who demonstrated the largest performance improvements. The scores represent total percent correct voicing perception of the consonants, averaged across all of the syllable utterances presented in a test. The values shown were based on at least three administrations of each test for most listeners.

Table 1. Median and quartile percent(%) correct voicing for final fricatives in syllables unenhanced, and with enhanced vowel durations. (n=15)

	Unenhanced	Enhanced
Q_3	70	96
Median	62	92
Q_1	55	89

For the syllables with unenhanced cues, average performance was 62% for this group of listeners. (For reference, note that normal-hearing listeners would obtain 100% correct perception of the consonants.) Thus, these listeners' voicing perception for the consonants was rather poor when the syllable's vowel durations were unenhanced. In contrast, the listeners' consonant voicing perception was quite good when the syllables' vowel durations were enhanced. The groups' average performance was 92%, which is close to normal performance for the unenhanced syllables. This reveals that enhanced vowel durations can improve voicing perception of final consonants for some hearing-impaired persons who have poor perception of those consonants in syllables without vowel duration enhancements.

The results are summarized in Table 2 of the study of consonant voicing perception for syllables with enhanced spectral cues. The scores shown represent tests of the 14 listeners who showed the largest performance improvements between the unenhanced versus cue-enhanced syllables (total N = 21). For the syllables without spectral cue enhancements the listeners' consonant voicing perception averaged 62%. However, a sizeable performance improvement was seen when the listeners were tested with the syllables containing enhanced cues. The listeners' average consonant voicing perception was 85% when the spectral cues of the consonant friction noises were enhanced. This finding indicates that emphasis of certain spectral cues in consonant friction noises can improve voicing perception of those consonants for some hearing-impaired persons.

Table 2. Median and quartile percent(%) correct voicing for final fricatives in syllables unenhanced, and with enhanced frications. (n=14)

	Unenhanced	Enhanced
Q_3	69	87
Median	62	85
Q_1	56	77

In both experiments some listeners showed little change in performance between the enhanced-cue versus unenhanced syllables. These were listeners whose voicing perception for the consonants in the unenhanced syllables was either very good or very poor. For the listeners with good performances, only minor improvements were seen for the cue-enhanced syllables, since these listeners showed near-normal perception for the consonants when the syllables were unenhanced. For the listeners showing very poor perception, several explanations may be offered for their lack of improvement for the cue-enhanced syllables. For example, they may have been experiencing tactile rather than auditory perception of the syllables.

The preliminary results of the two experiments reveal that enhancements of particular acoustic cues in speech may facilitate speech perception by persons with severe or profound hearing losses.

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NOISE REDUCTION FOR THE HEARING IMPAIRED

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ABSTRACT - A digital noise reduction technique was evaluated on normal hearing and hearing-impaired listeners. Processing signifiantly reduced the audibility of background noise. Although speech recognition scores did not improve with processing, all listeners preferred listening to the processed signal.

RÉSUMÉ - Une technique numérique d'atténuation du bruit a été évaluée chez des sujets normaux et des malentendants. Ce traitement a réduit de façon importante la perceptivité des bruits de fond. Bien que les résultats de la reconnaissance de la parole ne se soient pas améliorés, tous les sujets ont préféré écouter le signal traité.

A hearing aid is of limited use in situations where the signal-to-noise ratio is poorer than +10 dB (Erber, 1971; Gengel, 1971). While signal processing techniques have been developed to reduce the effects of additive noise, little has been done to evaluate the usefulness of such techniques for hearing aid applications. Weiss and Aschkenasy (1974) have developed a technique which works on a single degraded input (speech-in-noise), a situation typical of the input at a hearing aid microphone.

The method of operation is to obtain the spectrum of the square-root amplitude spectrum of the input signal. This spectrum-like representation of the signal is obtained for both speech plus noise and for noise alone. The second is subtracted from the first to yield an enhanced representation of the signal in which the noise content is greatly reduced. By inverse transformation, an enhanced power spectrum is obtained which, with the addition of phase information, is converted back to conventional time-dependent signals.

The purpose of the present experiment was to evaluate the effectiveness of this signal processing technique in reducing the noise level and in enhancing the intelligibility and comfort of speech degraded by additive background noise for normal hearing and hearing-impaired listeners.

METHOD

Ten normal hearing and five hearing-impaired listeners served as subjects. The hearing-impaired listeners had moderate to moderately-severe sensorineural hearing losses and were experienced hearing aid users.

The output of a tape recording of the CUNY Nonsense Syllable Test and of a continuous discourse passage was mixed with white noise (0 dB S/N) and recorded onto a single channel of a two-track tape recorder. The output of this tape recorder was low-pass filtered through an anti-aliasing filter with a cut-off frequency of 3800 Hz (slope of 120 dB/octave) and digitized via a 14 bit analog-to-digital convertor before being processed through a MAP 300 Array Processor, which sampled at a rate of 10,000 samples per second. The noise reduction process was implemented using the array processor and the output of the MAP 300 was passed through a 14 bit digital-to-analog convertor, low-pass filtered (cut-off frequency of 3800 Hz, slope of 120 dB/octave) and then recorded on the second channel of the tape recorder. Thus the test tape consisted of unprocessed speech-in-white noise (0 dB S/N) on one channel and the processed speech-in-noise on the second channel.

A total of eight NST scores were obtained in two sessions, four unprocessed and four processed. The order of presentation of conditions within a test session was randomized. At the end of each session, each subject was asked to indicate his preference for the processed or unprocessed signal and the reason for his preference.

RESULTS AND DISCUSSION

Comparison of the graphic level recordings of the unprocessed and processed speech tapes revealed that processing reduced the noise by 12 dB.

A trial-by-trial comparison of the NST scores of each subject (processed versus unprocessed conditions) reveals that all between-condition differences fall within the limits of the 95 percent confidence intervals, thus indicating that there are no significant differences in NST scores due to processing for individual subjects in either group. The failure of processing to improve syllable recognition scores, despite the measurable improvements in signal-to-noise ratio is in agreement with the findings of other investigators who have used digital noise reduction techniques with different speech materials and different types of noise (Lim, 1982).

The effect of processing was to reduce the bandwidth of the signal due to the use of a sampling rate of 10,000 samples per second and a low-pass anti-aliasing filter with a cut-off frequency of 3800 Hz. In addition, the spectral subtraction technique reduced the noise-like high frequency components in the speech along with the additive noise. Recognition of syllables contained in the NST is highly dependent on high frequency spectral information. There is a significant amount of energy in the frequency region between 3000 and 4000 Hz due to the large number of fricative consonants included in the test and due to the speech spectrum characteristics of the speaker who made the recordings. Some of this high frequency energy was cut out by the low-pass filtering employed. Use of a higher sampling rate and filter cut-off may cause some improvement in scores.

Syllable recognition scores (percent correct) were calculated for each subject for each of the seven subsets of the NST. Sets 1, 2, and 3 consist of voiceless consonants combined with the vowels /i/, /a/ and /u/, respectively (VC construction). In Set 4, voiced consonants are combined with the vowel /a/ (VC construction). Set 5, consists of voiceless consonants in combination with the vowel /a/, while Sets 6 and 7 consist of voiced consonants in combination with the vowel /a/ (CV construction). Mean scores for each subset by condition and group appear in Table 1. Inspection of the table reveals that the pattern of performance on the NST is similar for the normal hearing and hearing-impaired subjects. Performance is better for the voiced consonants than the voiceless consonants. Syllable recognition is highest on sets which contain consonants in combination with the vowel /a/ and poorer on sets in which consonants are combined with /i/ and /u/. This pattern of performance is consistent with that described by Dubno and Levitt (1981) and Levitt, et. al. (1978). Processing caused a slight decrease in the syllable recognition scores of the majority of the subsets; recognition scores were slightly better for Set 1 (/a/ in combination with voiceless final consonants) for the normal hearing subjects and Set 4 (/a/ in combination with voiced final consonants) for the hearing-impaired subjects. A more detailed analysis of consonant confusions was not carried out due to the small number of observations for each phoneme.

	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Set 7
Normal Hearing							
U	40.9	33.4	44.9	80.6	66.3	85.3	67.4
P	44.2	30.0	35.7	73.4	53.0	77.5	61.3
Hearing Impaired							
U	22.0	26.1	28.6	62.0	41.3	72.1	49.8
P	21.4	17.1	25.4	67.8	37.8	54.4	47.0

Table 1. Speech recognition scores (percent correct) on seven subsets of the Nonsense Syllable Test for the unprocessed (U) and processed (P) conditions by normal hearing and hearing-impaired listeners.

A positive result of processing was to improve the quality of the speech signal. At the end of a listening session, each subject was asked to indicate (by number) which of the four trials he preferred and to indicate the reason for his choice. All 15 subjects indicated a preference for the processed signal. The most common reason given was that the noise of the processed signal was less annoying and easier to listen to. This finding is similar to that of Cupples (1982) who evaluated the use of the same process for air traffic control use. One of the major benefits found was a lessening of listener fatigue associated with listening to speech-in-noise over long periods of time.

CONCLUSIONS

A spectral subtraction approach to the processing of a noisy speech signal failed to improve syllable recognition scores of normal hearing or hearing-impaired subjects on the NST. However, the processing did significantly decrease the audibility and annoyance of the noise contained in the original, unprocessed signal. Subjects were able to listen to the processed signal at higher levels than were possible for the unprocessed signal and also preferred the processed signal. This has an important implication for the hearing aid user. Many hearing aid users automatically turn down the gain or totally turn off their hearing aid in a noisy environment. Implementation of digital noise reduction processing techniques in amplification systems would allow the listener to function in a noisy situation comfortably without changing the gain of his hearing aid.

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ACKNOWLEDGMENT

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A SCHEME TO AID SPEECH PERCEPTION FOR PEOPLE WITH SEVERE HIGH FREQUENCY HEARING LOSS

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ABSTRACT - A scheme is proposed to aid speech perception for people with severe high frequency hearing loss. Formants and other features above 1KHz are extracted and represented with surrogates in the residual hearing range as the signal is passing through an electronic processor controlled by a microcomputer. The scheme aims to achieve minimum interference between the surrogates and the first formant.

RÉSUMÉ - On suggère ici un procédé devant aider les déficients auditifs à discerner les differents parties de l'élocution. L'information au dessus de 1KHz est extraite et représentée par un substitut entrant dans le champs auditif restant par un microordinateur alors même que le signal passe à travers des circuits électroniques. Ce procédé vise à garder au minimum l'interférence entre ces substituts et les sons originalement discernés.

Severe hearing loss due to sensorineural impairments can not be compensated effectively by conventional hearing aids. Thus, alternative approaches have been proposed to aid speech perception by presenting coded speech in visual, tactual, or auditory mode [1]. We consider the auditory mode the most appropriate for persons with severe high frequency loss since the auditory system, even impaired at the periphery, is still probably the best for perceiving speech information. However, to date the reported schemes and devices based on this approach have had only very limited success [1]. Their disappointing performance is probably due to the failure to encode important speech features distinctly and to minimize masking effects in the residual hearing range. Recently we reported a microcomputer-based realtime system for the development of an effective aid for the severely hearing impaired [2]. In this paper we propose a scheme using this system to encode the second and higher formants along with other speech features.

Our scheme is implemented on the microcomputer controlled electronic system shown in Fig. 1. For the present purpose we have assumed a residual hearing range from 100Hz to 1KHz. The system has 2 main channels: the hf channel and the lf channel. In the hf channel there are 3 subchannels which extract information from the speech signal in the 1KHz to 8KHz band and encode it in terms of surrogates in real time. The 2 tracking bandpass filters extract the strongest formants in the frequency ranges indicated, while the 4KHz highpass filter provides a voltage essentially due to the fricatives. The outputs from these filters are processed by the surrogate generators and the microcomputer. Generally, the amplitude of the surrogate is made to follow the amplitude of the filter output. The frequencies of the surrogates are set according to the scheme given in Table 1 for voiced speech. The "normal frequency", f_s, of the surrogate is the frequency indicated for Case 1 when f_s is outside a band of 200Hz centered about the first formant frequency f_1. The scheme for Case 2 has been designed to reduce masking effects. For example, if the output from Tracking Bandpass Filter 1 has a frequency of 1000Hz and f_1 is 300Hz, then the frequency of the surrogate is changed from f_s=250Hz to 100Hz. The frequency mapping operation is performed continually at intervals which vary from 5 to 10 msec, depending on the speech characteristics. For unvoiced speech, the output from Tracking Bandpass Filter 2 is mapped into the range from 240Hz to 500Hz and the output from the 4KHz highpass filter mapped into the range from 800 to 1KHz. Switch 2 is turned on whenever there is sufficient energy above 4KHz, and it remains on for about 8 msec after the energy has dropped below threshold in order to provide some transition between the surrogates and the first formant.

In the lf channel, the cutoff frequency of the lowpass filter is continually adjusted to equal to the first formant frequency so that other weaker frequency components are attenuated in order to reduce masking of the surrogates. For the same purpose Switch 1 is turned off whenever the output from the lowpass filter is below some pre-set threshold.

The results from our preliminary investigations are encouraging. Fig. 2 shows the spectrograms of the word "slash". The wide band spectrogram of the original word is given in (a), while (b) shows the narrow band version with frequencies above 1KHz removed. In (c) is shown the spectrogram of the modified word which has been encoded by our scheme. The surrogates are distinctly audible and they do not interfere with the first formant of the original word as they are shown in the spectrogram.

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ACKNOWLEDGEMENTS: This work was supported by a grant from the MRC of Canada.

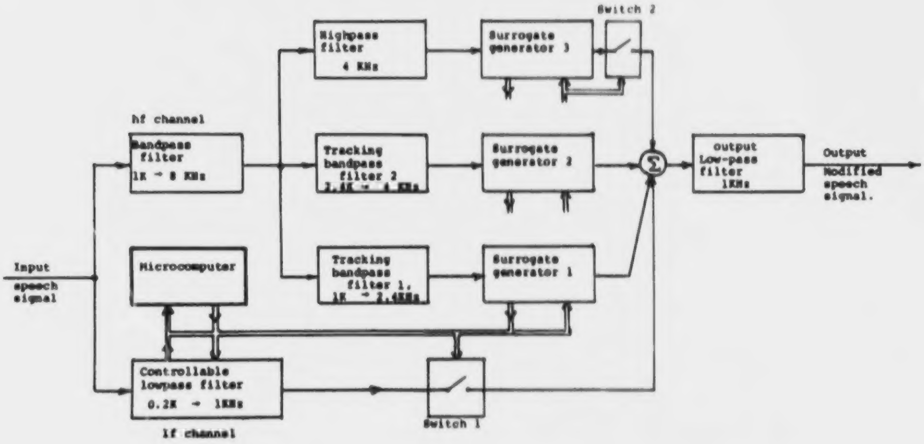
Input
speech signal
hf channel
Bandpass filter
1K → 8 KHz
Highpass filter
4 KHz
Tracking bandpass filter 2
2.4K → 4 KHz
Tracking bandpass filter 1.
1K → 2.4KHz
Surrogate generator 3
Surrogate generator 2
Surrogate generator 1
Switch 2
Σ
output Low-pass filter 1KHz
Output
Modified speech signal.
Microcomputer
Controllable lowpass filter
0.2K → 1KHz
lf channel
Switch 1

FIGURE 1. Microcomputer controlled electronic system for speech coding in real time.

TABLE 1 Frequency Mapping Scheme for Voiced Speech

Surrogate generator	Input Frequency	Frequency of Surrogate		
		Case 1 $\|f_s-f_1\|>100$	Case 2 $\|f_s-f_1\|<100$	
			$f_s<f_1$	$f_s>f_1$
1	1000 ↓ 2400	250 ↓ 480	100 ↓ 240	1000 ↓ 800
2	2400 ↓ 4000	480 ↓ 800	800 ↓ 1000	800 ↓ 1000
3	4000 ↓ 6000 ↓ 8000	800 ↓ 1000 ↓ 1000	N/A	N/A

Note: f_s = "normal frequency" of the surrogate.
f_1 = estimated frequency of the first formant.
All frequencies are given in HERTZ.

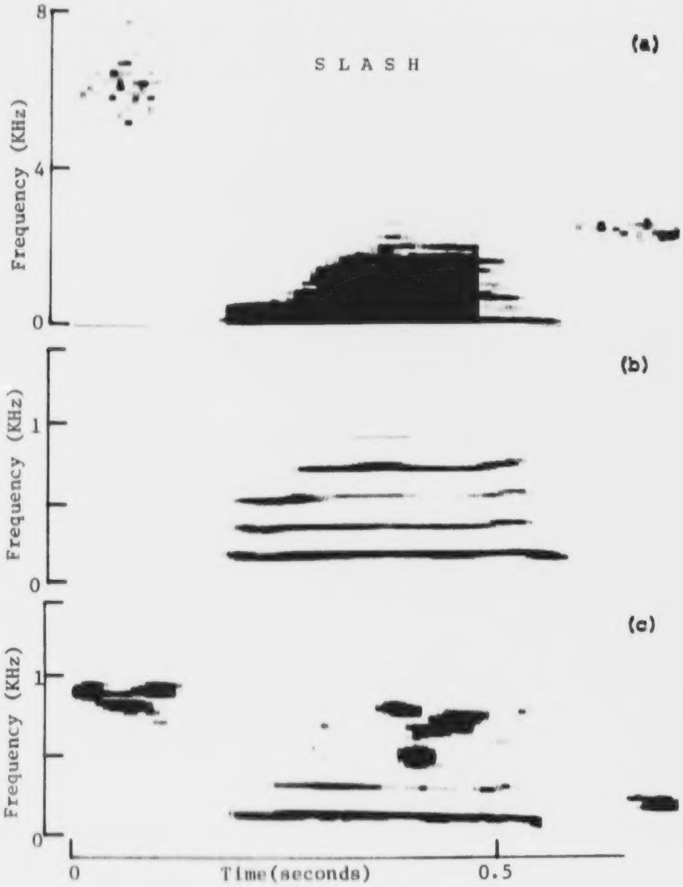

FIGURE 2. The spectrograms of the word "slash": a) wideband, b) narrowband (<1KHz), c) modified version with surrogates introduced.

EDUCATIONAL SUBTITLING FOR DEAF CHILDREN

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ABSTRACT - Subtitling of televised educational material has enormous promise in the education of the deaf. It is a means of both transmitting otherwise absent auditory information and simultaneously improving language skills. For subtitling to be effective, some degree of 'local' captioning capability is essential.

RÉSUMÉ - Le recours au sous-titrage, pour le matériel éducatif télévisé offre d'énormes possibilités pour l'éducation des personnes atteintent de surdité. C'est à la fois un moyen de transmettre des renseignements auditifs qui seraient autrement absents et d'améliorer les compétences du sujet en matière de langage. Pour que le sous-titrage soit efficace, il est essentiel d'avoir une certaine capacité de sous-titrage "locale".

Introduction

A five-year study of teletext subtitling ("captioning") of television programmes for the adult, post-lingually deaf was recently completed at Southampton University. This work had two major facets. First, the best ways of exploiting the resources of teletext for deaf-subtitling were examined, the principal research tool being controlled audience research in the deaf community. This culminated in the publication of Guidelines for subtitle editors(1) covering aspects such as text presentation rate and editing strategy, on-screen timing, screen position etc. Second, equipment and techniques for the efficient and economic preparation of subtitles were developed, resulting in the production of a special-purpose subtitling system (NEWFOR) which significantly reduces preparation times (2).

A large number of pre-lingually deaf are, however, effectively denied access to the new medium of subtitled television by their poorly developed language skills. Conrad (3) estimates that the median reading age of the deaf school leaver is 9 years; a level of attainment making it difficult to cope with the language used in television programmes. This renders unproductive any attempt to provide "easy" subtitles (of appropriate difficulty for the prelingually deaf) as part of normal broadcast services quite apart from the inevitably negative reactions of the abler post-lingually deaf viewers. The solution must lie in improved education of the deaf child. It is our belief that the subtitling techniques and expertise gained in our earlier work with broadcast captioning can be applied to positive effect in the educational context.

Subtitling and the Deaf Child

Poor reading skills are, in part, a natural result of the deaf child's inability to integrate visual (textual) and auditory (speech) information in the way that the normal child is able to do when learning to read. In addition, the normal child has access to a considerable store of televised educational material, covering an enormous range of subject matter, from which the deaf child is much less able to benefit. TV is both a visual and an auditory medium: it has, in fact, been described as "radio with pictures" (4). Subtitling of instructional programmes has enormous promise in the education of the deaf for two reasons. It is a means of both:
(a) transmitting educational information more effectively and, simultaneously,
(b) improving the language skills of the deaf child.

Television is also enjoyable and, therefore, motivating. It is not surprising that evidence suggests subtitling is indeed very effective in the education of the deaf (5). Our observations suggest this view is widely held by teachers of the deaf. We have witnessed several attempts to produce ad-hoc subtitles to accompany television programmes in the classroom, generally using quite inappropriate "technology" such as overhead projectors and even text written on large pieces of cardboard held close to the screen by the teacher. With modern microcomputers, video recorders and other microelectronics devices, there should be no need to adopt such desperate remedies. A much preferable approach is to transfer existing technology from the domain of broadcast captioning into the area of educational subtitling in schools for the deaf.

Provision of a Captioning Service

Many factors hinder the development of a 'central' schools captioning service by the broadcast authorities. The principal drawback is the high cost of subtitle preparation by conventional means. Other problems include the impossibility of providing subtitles with a level of linguistic difficulty appropriate for all children. Further, the value of such a service is limited by the difficulty of recording and storing those programmes which are transmitted at times inconvenient for viewing by virtue of the school's timetable. (Teletext subtitles cannot be recorded on a conventional video cassette recorder as their bandwidth exceeds that of the VCR).

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Many of these problems would be solved by establishment of 'local' captioning facilities within the schools - an approach usually favoured by the teachers themselves. The teacher is, of course, in the very best position to judge the language abilities and difficulties of her class of children; and so to set the specific educational goals of any given lesson and tailor the subtitle content to achieve these goals. Local captioning will, however, only be feasible if the facility is low in price, efficient in preparation time, and can be used by a teacher untrained in computing.

There would, indeed, be considerable potential in a system simple and robust enough to allow captioning by the pupils themselves, as well as the teacher. This would allow a hitherto unattainable degree of interaction and feedback in the classroom. For instance, the VCR could be paused and the children invited to supply a missing keyword in a subtitle. Such a facility could also be used, in the absence of background video, as an inter-pupil communication device or an "electronic noticeboard" for the school.

In our opinion, however, the existence of 'local' facilities for captioning does not remove the onus on broadcasters to subtitle childrens' educational programmes. Teachers of the deaf should not exercise a monopoly over the language input of deaf children, and there is an urgent need for the widest range of captioned materials from all sources. One attractive scheme could be for broadcasters to produce a "master file" of subtitles for major educational programmes, which could then be transmitted over air (by telesoftware) to individual schools' microcomputers. Schools would then have readily available raw material which they could adapt or edit to suit their own educational purposes.

Research Issues

Much research remains to be done on the educational effectiveness of subtitled video material and ways of optimising this. The research presupposes the existence of suitable subtitling equipment. We envisage an iterative process in which educational requirements are defined by discussion with teachers of the deaf and classroom observations; followed by the design of hardware and software to meet these needs. The 'new generation' subtitling system can then be used as the basis of further educational research, and so on.

Any system produced must facilitate subtitling within the school, while being easy to use and inexpensive. This will be best achieved by a hardware configuration based on commercial microcomputers and video recorders, already standard equipment in the schools. The tasks involved are subtitle generation, timing, display and storage. The techniques adopted for these tasks are not independent, but strongly influenced by the fundamental choice of 'closed' (separately encoded) versus 'open' (integral with video) captions. This choice will have implications not only for the engineering design of the system but also its operating characteristics and, therefore, its educational effectiveness.

Conclusions

Subtitling of video material can assist the education of the deaf in two ways. First, subtitles function to transmit the auditory content of the programme and so serve to reduce the handicap of the deaf child. Television programmes can thus support the teaching of a wide curriculum just as they do for the normal child. Secondly, subtitles can increase and enhance pupils' knowledge of vocabulary and grammar and thus contribute to general literacy.

To profit from these advantages, we are engaged in transferring technology devised for broadcast teletext subtitling into the area of educational subtitling. As this is likely to have a profound impact, all those concerned with the education and rehabilitation of the deaf should take an interest in these developments.

Acknowledgements

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SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 13

SERVICE DELIVERY PROGRAMS/
PROGRAMMES DE PRESTATION DES SERVICES

SELECTION OF A COMPUTER INTERFACE SYSTEM FOR THE MOBILITY IMPAIRED ADULT

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ABSTRACT - Selection of most appropriate interface system for the mobility impaired adult is outlined. Considerations such as control movement, interface, system feedback, keyboard set up, and scanning mode are discussed.

RÉSUMÉ - Le choix de l'interface la plus appropriée pour les adultes à mobilité limitée est décrit. Les considérations comme le contrôle des mouvements, les interfaces, la rétroaction du système, la configuration du clavier et le mode de balayage sont abordées.

The major goals in selecting the most appropriate computer interface system for the disabled adult are to allow access to all the functions of the computer that the user may wish to make use of, and to select a system through which the user can attain optimal speed and accuracy. The selected interface system should make good use of strategies which aid in speeding up and improving accuracy of entry. The chosen system should utilize the largest number of independent signals or inputs the user is capable of making.

Assessing for the most appropriate interface system is part of the overall rehabilitation assessment where such factors as ability to comprehend and remember directions, work tolerance, perceptual abilities and optimal positioning have been reviewed and taken into account.

Interface system selection involves:

- selection of the user's body part and actions which will activate the interface
- selection of the interface and mounting system

and if applicable

- selection of keyboard layout
- selection of scanning mode

Once a priorized selection of possible interface systems has been chosen objective comparative measurement of speed and accuracy of text entry using these systems is made. This stage of the assessment may be computer based or may take the form of a traditional typing test where speed is determined in words per minute.

Assessment of Controllable Actions and Control Sites

To establish a repertoire of useable movements or actions all body movements are assessed systematically. Movements over which the user has reliable voluntary control, which he can initiate, control and return to resting position without compromising good muscle tone, threatening vulnerable joints or causing undue fatigue are recorded. These may include puffing and sipping, tongue movements, head movements etc.

Selection of Interfaces and Mounting Systems

Interfaces or switches and mounting systems which make optimal use of the users controllable movements are chosen. The interfaces should compensate for the limitations of the user i.e.:

- if limited range of motion but good control: small switches in close proximity
- if poor control of movement but large range of motion: large switches with increased spacing mounted in range where movements are reasonably controllable, and aids to stabilize body part used
- if weak movements: switches requiring no force, mounted so that movement is not against gravity

Ease of set-up, reliability and cost are also considerations.

Keyboard Layout

The standard "qwerty" layout of the keyboard although familiar to many was not designed for single digit or scan-select entry.

If a standard computer keyboard is not used many interface systems, whether they use external keyboards or screen mounted keyboards accessed through switch entry, allow for customized keyboard layout. The keyboard may be laid out in rows and columns or linearly. Characters may be laid out in groups to allow for group scanning. Characters may be distributed in alphabetical order, in the qwerty layout or in statistical frequency of use distribution where the most used characters is closest to the resting position and characters which frequently occur together are in close proximity of each other. The keyboard may be set up in levels, where further keyboards can be accessed through the first or home keyboard. Considerations in choosing a set up are: ease in finding any given character and speed in reaching chosen character. To speed up entry commonly used words or phrases may be included as choices in the keyboard set-up, allowing entry of an entire word or phrase with one selection.

System Feedback

Feedback enhances the accuracy of input. It is especially important for persons with perceptual difficulties. Feedback may take an auditory, visual, tactile or proprioceptive form. Feedback may come from the switch, the scan select mechanism or the computer itself. When using a screen mounted keyboard it is important that the person be able to keep track of the cursor. This may be facilitated by various methods of highlighting the choice the cursor is at and by indicating when the cursor is moving,through an auditory or visual signal. The person should also receive feedback to indicate when a selection is made.

Methods of Entry

The various methods of entering data into the computor can be categorized into three major categories.
Direct Selection:
modified standard keyboard-using stabalizing aids such as keyguards or wrist supports to improve control and accuracy or single digit entry (i.e. using mouth stick, headpointer, etc.) with the aid of a keylock device to hold down shift and control functions
adapted keyboard- expanded keyboards, miniaturized keyboards or keyboards which recieve alternate inputs i.e. light beams
Coded Selection Using Condensed Keyboard: I.e. numeric pad
Switch Entry: may use coded entry i.e. morse code, dedicated scan select device or a guided cursor over a screen mounted keyboard. Switches with single to five functions are commonly used.
Direct selection is the most demanding but fastest method of entry.

Scanning Modes

When using switch entry there are often several scan options to choose from.
Directed Scan-the user directs the cursor using a multifunction or position proportional switch.In row column layout a five function switch is most commonly used where four functions direct the cursorin the four directions and the fifth function selects the character.
Step Scan -each switch input moves cursor one choice further-useful if timed release of switch is difficult
Group Scanning-Characters are laid out in groups, first the appropriate group is chosen and then the desired character
Automatic Scan-Cursor automatically scans through choices-necessary when only one or two function switches can be used-timed selection is required although it is possible to anticipate when selection should be made-may be activated by switch input or continuously scan through choices
Automatic Select-if cursor remains on given choice for a period of time selection occurs automatically
Scan Speed-Maximal speed while maintaining accuracy is chosen- beside regular adjustable speed there are several other options: velocity proportional(the more pressure is applied to the switch the faster the cursor moves), variable speed (begins slowly and speeds up)

Following selection of possible interface systems, taking into account the above mentioned factors where applicable, the user is familiarized with the interface systems. the final selection is based on objective comparative measurements of speed and accuracy of text entry. When the appropriate system has been selected "fine tuning" of adjustable options may improve entry further. As the needs and abilities of the user change the system may need to be changed accordingly.

Note:In this paper "interface system" and "interface" have the following meaning:
Interface System:the switch, control or interface and the mechanism which interprets the switch entry to the computor
Interface: the mechanism which the indivisual directly controls i.e. switch, keyboard.

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WORKLOAD OF SERVICE DELIVERY REHABILITATION ENGINEERS

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ABSTRACT - Seven Rehabilitation Engineers providing service delivery were asked to summarize their activities of the past reporting period.

RÉSUMÉ - Voici le compte rendu des activités pendant la période de référence de sept ingénieurs en réadaptation qui ont assuré le service de la mise en place des prothèses.

This paper is an elaboration of data requested by the O'Donoghue Rehabilitation Institute Administrator. He requested department heads to determine departmental staffing requirements for an inhouse census of 55-65 clients. These staffing requirements were to be based on staffing of similar rehabiltitation hospitals across the country.

While to my knowledge no norms have been published for RE service, I did call several Rehabilitation Engineers to learn of their activities.

As I was gathering this information, it occurred to me it would be of interest to other Rehabilitation Engineers.

Because each rehabilitation engineer's activities and report style differ, the data is not intended to compare RE productivity but rather to show several "vignettes" of RE as practiced today.

Case 1:

A former Occupational Therapist completed the University of Rehabilitation Engineering Masters Program. Now at a large southwest medical complex, she performs a mix of research and service delivery.

Her activities for January-September of 1983 included 34 evaluations (some of these were multiple visits).

17 of these evaluations were for seating
8 for pressure sore management
9 for special devices
10 inservices at 9 different facilities

- Consulted with a school region setting up a special device laboratory.
- Consulted with Shriner Hospital in areas of seating and gait.
- Consulted with three schools to solve special problems.
- Consulted with a county hospital.
- Worked at the Veterans Administration once or twice a week on pressure sore management problems.

She estimates 60% of her time is spent at the complex and 40% outside the complex.

Case 2:

A rehabilitation engineer who worked at two federally funded rehabilitation engineering centers completed the U.Va. RE Masters Programs. Presently he is at a state hospital complex in the southwest.

In this center, the orthotics department measures and fits wheelchair seating inserts.

From October 1, 1982 to October 1, 1983, folders on 47 projects were started.

32 projects were completed
4 consultations/evaluations were done

Of the incomplete projects:

6 were active, but incomplete as of 10/1/83
1 was not completed because client progressed beyond the need for the device
1 was rejected by client
3 were referred to other departments

During October, initial client referrals had been made from both The State Vocational Rehabilitation Department and the Veterans Administration. It is expected client referrals from these and other sources will increase, making rehabilitation engineering less dependent on inpatients.

Case 3:

A rehabilitation engineer has worked at four centers in the US and Canada.

Presently at a midwest center, he has estimated only 2 1/2 hours of his average day is and 5 to 5 1/2 hours of his technician's time are billable.

Case 4:

A rehabilitation engineer has her undergraduate degree in mechanical engineering. For about a year after graduation she was a research assistant in a brace and limb shop. From there she completed the U.Va. RE program. Presently she is one of four RE's working for a South-Atlantic state vocational rehabilitation department.

o She designs home modifications and suggests wheelchair ramps or lifts and bathroom modifications.

o Another part of her job is liaison work with clients and vendors of car and van modifications. The rehabilitation engineer conducts functional evaluation of the client, a driver evaluation, and writes specifications for van/car modifications. Once the modification is complete, the rehabilitation engineer checks its quality.

o A third part of her job is job site modifications to allow clients to return to old jobs or reduce the difficulty clients are having at their present jobs.

It is estimated each of the four engineers in the department does about 75 projects per year.

The Rehabilitation Engineer further explains:

"I would like to make a few additional comments on my position with Vocational Rehabilitation because it is such an unusual one; this agency is the only state agency in the country to use engineers in this role. I do not operate on a fee basis; funding for projects comes from each counselor's caseload budget, depending on the client's financial status. If the client is not financially eligible (i.e. they make over a certain amount of money), my service is still available. We are also available for community consultation, and spend probably 15-20% of our time working with sheltered workshops, non-VR clients, talking to various rehab professionals and groups, and providing consultation to industries on ways to make their plants accessible to the handicapped".

Case 5:

A rehabilitation engineer received her undergraduate in Civil Engineering, and worked parttime at the University of Virginia REC while completing her Masters in Biomedical Engineering. Her first job was as a service delivery rehabilitation engineer in the Mid-Atlantic area. Presently she is working at another Mid-Atlantic hospital. The hospital has 40 rehabilitation beds and 100-200 outpatient clients per day. Her job is exclusively wheelchair prescription and insert fabrication.

o She and the two technicians fit 3-4 inserts per day. The unit is barely profitable; mostly due to a helpful arrangement with the wheelchair vendors. In return for getting half the normal wheelchair markup, the hospital wheelchair and seating unit perform setup and final adjustmentsof client wheelchairs.

Case 6:

A rehabilitation engineer has worked at several centers in the southwest. He estimated 3-400 problem statements are generated for rehabilitation engineering each year; but due to lack of records, no other information is available. He did not present the two papers accepted at the last Rehabilitation Engineering Conference because there were two clients in Intensive Care needing his services.

In order to justify his job he has taken over supervision of the 5 biomedical technicians, and may in the future supervise the pulmonary and laboratory technicians.

Case 7:

A rehabilitation engineer received his undergraduate degree in rehabilitation. For two years after graduation, he performed wheelchair or device modifications requested by the the PT or OT department of a northeastern state institution for the severely and multi-handicapped. After graduating from the U.Va. Rehabilitation Engineering Center, he now performs RE service delivery to a north central state. For the last recording quarter he performed a total of 55 separate requests.

5	worksite modifications
23	devices for vocational use
4	adl home modifications
12	adl device equipment modifcations
11	educational enhancement/modifications of equipment.

These figures only represent those consumers handled by the engineer; far more informational and related requests were handled by other staff.

Summary: This paper has sketched seven Rehabilitation Engineering service delivery operations. The many ways of reporting RE activity make it difficult if not impossible to compare activities between centers. If further comparative study of RE workload is comtemplated, serious thought should be given to standardizing activity reports.

Hopefully these sketches are only the start of an ongoing, perhaps yearly, summary of RE service delivery activity.

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PROVIDING POSITIONING SERVICES TO A PEDIATRIC POPULATION IN A RURAL AREA

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ABSTRACT - Pediatric clients in rural areas positioned in postural seating systems require a flexible, specialized service delivery system. This paper addresses patient problems that are accentuated when they live in rural areas, and outlines one service delivery system developed to effectively manage these problems.

RÉSUMÉ - La clientèle pédiatrique rurale qui est astreinte à la position assise doit jouir d'un service de livraison spécialisé souple. La présente communication traite de problèmes particulièrement graves pour les patients qui habitent à la campagne et décrit un service de livraison permettant de surmonter ces problèmes.

One important aspect of positioning is the custom fabrication and/or modification of postural seating systems that provide maximum patient functioning and prevent musculoskeletal deformities. Providing positioning services for a pediatric (0-21 years) population addresses a myriad of complex and interrelated patient needs. Additional patient needs are encountered when providing these services in a rural area. One approach to overcoming these obstacles has been developed through a tertiary program of the Division of Developmental Disabilities*, University of Iowa Hospitals and Clinics. The majority of patients receiving services through this program have a primary diagnosis of either neuromuscular dysfunction such as cerebral palsy, or spinal cord abnormalities such as spina bifida. This program interfaces with local service providers from several state agencies serving developmentally disabled persons.

Although common difficulties exist in serving most positioning patients, the authors present the following as problem areas which become accentuated when the client is located in a rural area:

1. To adequately meet the complex needs of patients, a comprehensive interdisplinary evaluation is necessary. Often this spectrum of health care specialists is not easily accessible to rural patients.
2. Transportation issues continually arise when serving a rural population:
   - the necessity of patients traveling great distances when being served at the tertiary care facility
   - adaptability of the postural seating system for use in the local school and family vehicles
3. Adequate information exchange between all persons involved with the patient is critical for continuity of care. Maintaining the following lines of communication are problematic in rural areas:
   - developing a treatment plan for the patient between the tertiary center and the local service providers
   - obtaining feedback from local service providers regarding patient status and problems with the treatment plan
   - communicating to the families the importance of following through with the treatment plan, and updating service providers concerning the patient's status
4. Body systems of positioned clients require regular monitoring. Common problems in positioned patients that are often more difficult to identify and remedy in rural areas where followup may be infrequent include:
   - significant weight loss or weight gain
   - skin breakdown
   - rapid growth spurts
   - advancement of musculoskeletal deformities
5. Maintenance and repair of postural seating devices are essential in order to provide maximum benefits to the patient. Trained technicians to perform these services are frequently unavailable in rural areas.

*This service is provided by the Division of Developmental Disabilities, Department of Pediatrics, The University of Iowa Hospitals and Clinics. The site of services of the Division is the University Hospital School, Iowa City, Iowa. The programs of the Division serve as Iowa's tertiary resource for disabled children of the State.

A Positioning Service Delivery System for Rural Patients

The following flow chart outlines the Division's positioning service. This service delivery system is directed at reducing the attendant problems in serving rural patients.

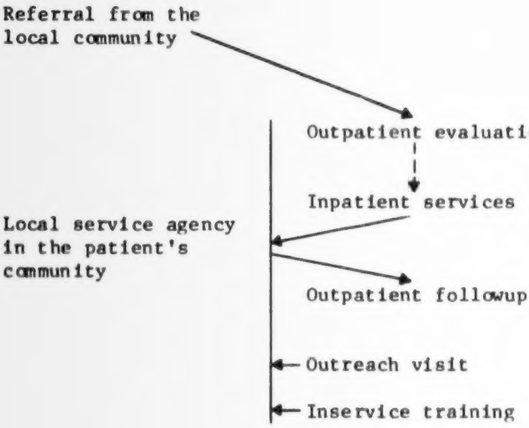

Figure 1.

Outpatient Evaluation: Initially, the patient is seen in the outpatient clinic by an interdisciplinary team who conduct a comprehensive evaluation of the positioning needs. Locating this service within a large tertiary care facility has provided a cost-effective method of obtaining interdisciplinary expertise. During the evaluation, specific attention is focused on body systems typically affected by positioning a patient. The patient's functional abilities within various environments (i.e., home, school, community) are also evaluated. In order to ease transportation needs, certain clients may utilize University Hospital's transportation system.

Inpatient Services: When a prolonged evaluation is indicated, when fabrication of a complex seating system is required, or when the patient's problems require acute care, the patient can be admitted to the inpatient unit. Benefits of the inpatient admission include:

- an extended evaluation by the interdisciplinary team of the newly fabricated seating system
- an opportunity for a group meeting among the local service providers, family members and the interdisciplinary team to develop the treatment plan
- provisions for continuation of the educational, recreational and social activities of the patient
- overnite accomodations for the family when their presence is critical to the patient admission (e.g., young patients, transportation difficulties)

Outpatient followup: Regular reassessments of the patient in the seating system are provided for monitoring the body systems and patient functioning. Followups are used to update treatment plans, and to exchange feedback by everyone involved with implementation of the treatment plan. Minor fabrications are completed at this time for maintenance and repair of seating systems.

Outreach visits: Members of the interdisciplinary team can travel to local areas whenever indicated to assist with problems such as:

- interfacing the positioning system with local transportation and/or school setting
- instructing local service providers and/or family members in the use and care of the seating system, the conducting of periodic skin checks, and the monitoring of other body systems
- utilizing outreach clinics to evaluate patients that are potential referrals, and providing consultation for positioning needs that cannot be met through local resources

Inservice training: Knowledge exchange at the tertiary care facility is provided to local service agencies in order to:

- update local professionals regarding innovations and new technologies for positioning
- obtain feedback from local service providers regarding the quality of service
- discuss with local service providers their current caseloads and consider potential referrals

Summary

Meeting the complex positioning needs of rural pediatric patients requires a flexible service delivery system. A combination of inpatient and outpatient services has proven to be a satisfactory method of service delivery for meeting the needs of this special group. In order to maximize the efficiency of professional care, most services are provided through a large tertiary care facility. A substantial effort is made to coordinate all activities with local service providers in order to assure adequate continuity of care.

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BASIC CONSIDERATIONS IN ADAPTED EQUIPMENT DESIGN

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ABSTRACT - Basic considerations in the choices and design of adapted equipment are described using key questions and common devices.

RÉSUMÉ - On décrit des considérations de base pour choisir et concevoir des équipements adaptés en utilisant des questions-clés et des dispositifs courants.

Adapted equipment refers to any device or tool modified to meet a special need. These adaptations range from simple to complex and may be made by occupational therapists, orthotists or rehabilitation engineers. Regardless of complexity, there are several basic considerations that must be made in helping the client decide which adapted equipment best meets his/her individual needs.

First the need must be identified. What are the critical tasks to be performed? For example, does someone really need to measure using a ruler or micrometer or would two jigs accomplish the quality control manufacturing task? Is the measurement needed to record length or angle or is it required to determine whether or not the part meets design specifications? Does an object really need to be held or could it be stabilized using a vise, vise grip pliers or a spikeboard? Is it necessary to pick up a glass or would a long straw work just as well.

Once critical tasks are determined, the next step is to describe which tasks or parts of tasks are difficult for the individual and why. Decide whether the problem is due to limited range, muscle weakness, limited endurance, slow speed, poorly controlled movement, or a combination of factors. Then decide whether or not a device is needed and if so what it needs to do. For example is holding, cutting, hitting or transporting needed?

Once the type of needed device has been identified, look for a suitable tool that will meet the need. Equipment catalogs, mail order firms specializing in notions, discount stores, parts departments or speciality stores may have the needed item, switch or handle style. Another option is to ask individuals who perform similar tasks about the types of labor saving devices or gadgets that are available. A jewelry or fly tying jig may work just as well in a dental lab. Consider whether or not a current device designed for another purpose could be used to meet the need. Suction cups, non-skid mats, rubber bands or tape all can be used to increase friction. One handed cutting can be accomplished by rocher knives, pizza wheel cutters or curved blades on some styles of paring knives. Barbeque tongs or reachers used by automechanics to get screws from engines may be adapted for home use. Perhaps a different brand or model of a current device might meet the client's need. Common examples are choices between electric or manual typewriters, the difference in balance points on different brands of electric drills, the variations in control knob, shape and location on appliances, color coding options, push vs. twist control motions, and utensil shape. For example, a mug with a T shaped handle is much easier to hold using tenodesis motion than is a tea cup with slanted sides. Felt tip pens require less pressure than ball points, styles vary in diameter, and clips or elastic may be added to increase stability. Ease of storage and weight must also be considered for some devices.

If a device is not available the rehabilitation team must decide if a device is really needed. Could the method be adapted rather than the tool; could the job description be modified, ie is the task essential; can someone else help; and does the client want to do the task? Also consider how often the task needs to be done eg. once/week vs. ten times daily.

If a device is still needed and none is commercially available then construction decisions include cost, construction skill and time available. Sometimes a homemade prototype might be tried before purchasing a more expensive model or contracting for construction. Considerations during actual construction include human function, eg. will the device fit the client's hand or foot; whether or not materials are safe, eg. will they splinter or break; and whether the device can be used by more than one person or for more than one purpose. Can an existing tool be modified or must an entirely new device be designed? Refrigeration insulation, foam curlers, bicycle grips, or rolls of tape all can be used as trial built up handles for individuals with limited grasp. Magnets as well as weights can add resistance. Lever arms may be lengthened on many controls.

Ideally, the trial device should be constructed by a person skilled in using that material (wood, metal, plastic, etc). During the trial period determine whether or not the device accomplishes its purpose. Consider its shape, weight and what could be done later to improve appearance. The trial may indicate that the device is not all that is needed or that the problem may be more complicated than expected. The first prototype often needs modification, but may be useful in identifying what else needs to be done.

The rehabilitation team should work together sharing skills and complimentary roles in order to identify problems, postulate ideas, construct and modify the devices and provide work or clinic trials. Library resources and equipment data banks should be consulted to determine what items have been tried in the past. Manufacturers can also be contacted to identify product design problems or suggest new ideas.

In this age of computers and advanced technology, simple gadgets and minor design modifications still can be used to improve client function. We need to be sure that our current students understand the basic considerations well as the advanced concepts in adapted equipment design.

EMPHASIS ON FUNDING

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ABSTRACT - The focus of this article is on the positives encountered in the search for funding. Rehabilitation engineering services are entering a competitive market for limited dollars and must develop an awareness of the requirements for entering this arena.

RÉSUMÉ - La présente communication traite de la réalité qui entoure la recherche des fonds. Les services de technologie de la réadaptation arrivent sur un marché où la concurrence est vive pour se partager des sommes limitées et doivent devenir conscients des exigences avant de s'aventurer sur ce terrain.

EMPHASIS ON FUNDING

We've come a long way, Baby! For the last eighteen months, the staff has struggled to secure payment for the services provided by the University of Tennessee's Rehabilitation Engineering Program. During this time, a greater margin of success has been noted. The headway made can be attributed to dedicated clients, client advocates and to a variety of concerned professionals in our program and elsewhere, notably Sandy Enders and Virginia Ruggles. Combined efforts have led to more acceptance and payment for prescribed services from traditional third-party payment sources, i.e., private and group health insurance, Medicaid of various states, Medicare, etc. Indeed, the ground has been broken and the time is ripe to pursue such sources. Locating secure funding, however, will continue to be a formidable and challenging task for those involved in provision of rehabilitation engineering services on a fee-for-service basis.

The difficulties of obtaining funding relate to the very newness and uniqueness of such services. Rehabilitation engineering is new in the health care delivery system. Proof of worth and cost/benefit is required for acceptance in the vast arena of medical technology currently available. Such acceptance then permits entrance into the competition for payment of services. Funding sources want to know 1) what they are paying for, 2) how long it will last (durability and adaptability), 3) the value or benefits to the client (patient) and 4) if the product or service meets the objectives it was intended to meet. Rehabilitation engineering, a unique endeavor, has too short a history to demonstrate long range cost effectiveness and/or the overall benefits derived by the client.

In the past, rehabilitation engineering programs have been funded, for the most part, by a variety of state and federal grants, primarily for research. Often such research projects could focus on only one aspect of client need rather than the overall rehabilitation goals. Time or limitations of funds tended to provide services for too few of the disabled client population who could benefit from such services. Until the last two or three years, traditional funding sources were seldom faced with a request for such services.

The University of Tennessee's Client Service Program is receiving increasing numbers of referrals resulting in increased demand and need for the services offered. Funding sources are acknowledging and paying for rehabilitation engineering services (approximately 40% of our 1983 clients have been Tennessee Medicaid recipients). Medicare has recently provided payment to several Medicare eligible clients for services provided by this program. As the need increases, funding sources will be pushed to develop and utilize payment criterion for prescribed rehabilitation engineering services. Standardization of services and payment will allow provision of more services for a larger client population. Unusual, one-of-a-kind services will continue to require supportive medical documentation on an individual review basis. Appropriate, specific information to the funding source documents the medical necessity and justifies payment. Each payment approval of "different" services paves the way for future payment on other unique services. Continued or renewed acceptance of services for payment will require validation by the prescribing health care professional, the provider of services, the client/consumer who actually uses and benefits from the services, and the funding sources as to the "rightness" of payment. Widespread public acceptance of rehab engineering services can create social trends that produce change in traditional payment sources. Public opinion and demand for services that actually work for the client tend to stimulate resources and promote a viable program image. Professional approval tends to generate more referrals for service. Satisfied clients are a program's best advocates.

The need for general public acceptance points to the need to properly educate the public and the professional community about rehabilitation engineering services. Many health care professionals have little knowledge of the availability and range of services offered. More education of public officials and legislators is required to promote acceptance. Continued educational efforts are needed to dissolve or dilute the social, cultural and attitudinal barriers towards the disabled that still exist in our society. The legislation of the last decade has provided the legal mandate needed by the disabled to obtain long denied rights to a more "normal" life. Such hard fought-for rights will not be easily given up by a more vocal, visible and productive disabled population.

Assuming that greater acceptance is now a possibility, such acknowledgment points to the lack of adequate service programs and the trained personnel needed to meet increasing and varied demands placed on the few existing centers in the United States and Canada. Education will play a key role in helping to increase service programs and to produce the trained personnel needed.

There seems to be a positive interaction of events that indicate a more favorable outlook for payment of rehabilitation services. 1) The need for services is becoming more evident. 2) Disabled clients are more vocal and visible, demanding the services they need to live up to their potential. 3) The curtailing of Federal and State grant funds is forcing rehabilitation engineering to look to other more stable sources of revenue. 4) Funding sources are being faced with new and varied demands for services and are providing payment in many cases. Some sources such as Medicare, are in the process of developing payment criterion. Such criterion should result in payment of approved services for Medicare eligible clients. It is anticipated that Medicare will cover approximately 60% of the actual cost. The client, family or other sources will be required to pay the balance. 5) More health care professionals are aware of and using rehabilitation engineering services where available. 6) Rehabilitation engineering programs are providing better documentation and follow-up in order to justify payment. 7) More devices, which have been proven successful, are becoming commercially available making provision more cost effective (as opposed to one on one design).

CONCLUSIONS

The doorway to more stable funding is opening but there is still a long way to go. The rehabilitation engineering field must continue:

1) to take an active role in the education of the public, the consumer, the funding sources, public officials, legislators, etc.

2) to assist the disabled in the fight for the right to have as "normal" a life as possible.

3) to develop new and better products and services to meet the needs of the disabled, utilizing consumer input and guidance.

4) to utilize a team approach to problem-solving involving a wholistic approach to treatment.

5) to develop and document methods of client and product evaluation and follow-up.

6) to maintain contacts with the commercial component of the health care industry to provide ongoing product evaluation for upgrading product design based on actual client usage.

7) to promote rehabilitation engineering by increasing exposure, utilizing all communication forms, i.e., books, articles, newspapers, TV, etc.

8) to educate health care professionals as to the services, products and benefits of rehabilitation engineering services.

MEDI-CAL REIMBURSEMENT OF REHABILITATION TECHNOLOGY

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ABSTRACT - Third party reimbursement plays a critical role in the acquisition of rehabilitation technology. Analyses of one reimbursement program, MediCal, have identified gaps in communication among health care and engineering professionals which affect user acquisition of state-of-the-art rehabilitation technology.

RÉSUMÉ - Le rôle du remboursement par un tier est critique dans l'achat des appareillages de réadaptation. L'analyse d'un programme de remboursement, nommément MediCal, a mis en lumière les lacunes du dialogue entre les professionnels de la santé et les ingénieurs, lacunes qui privent les usagers des appareillages de réadaptation les plus récents.

Introduction:

"By deciding which medical procedures are eligible for reimbursement, health insurance programs possess the potential to affect significantly technology use and health care spending."[4]

Rehabilitative assistive devices, historically, have been categorized under the reimbursement category of Durable Medical Equipment (DME). DME is defined as equipment that: (1)can withstand use, (2)is primarily and customarily used to serve a medical purpose, (3)generally is not useful to persons in the absence of an illness or injury, and (4)is appropriate for use in the home. Traditional examples of DME include: wheelchars, hospital beds, canes and crutches, walkers, oxygen therapy equipment, and bathroom accessories.

There is a paucity of data regarding reimbursement of Durable Medical Equipment (DME). DME is often subsumed in the larger category of 'Other' in statistics that are relevant to government or private sector reimbursement of health services. Only one study exists which documents baseline information regarding the demographics of Medicare reimbursement of durable medical equipment.

This study was conducted under a three year contract between Exotech Research & Analysis Inc. and the Health Care Financing Administration's Office of Research, Demonstration, and Statistics to conduct a DME research and demonstration project. The study results, published in the Winter 1981 edition of Health Care Financing Review, concluded that:

> The younger, physically disabled population poses a special problem with respect to provision of DME and reimbursement for it. In interviews with State Medicaid personnel, the point was made that amounts authorized for payment under HCFA rules were frequently insufficient, particularly for customized, heavily used equipment required for this special population. When the amount authorized for Medicare/Medicaid reimbursement does not cover the total cost and if the beneficiary is indigent, he/she may effectively be denied access to the needed equipment [5].

MediCal: An Analysis

"The Medicaid program has emerged as a primary source of funding for services to disabled people."[6] Exploratory analysis of California's Medicaid program, MediCal, provides a benchmark for future research and policy considerations.

Title 22, Division 3, Section 51521 of the California Administrative Code states that:

> (a)Reimbursement for rental or purchase of durable medical equipment shall be the usual charges made to the general public not to exceed: (1)The maximum reimbursement rates listed in this section. (2)Reasonable maximums for equipment reimbursed "By Report". (3)When applicable, the Lowest Charge Levels established pursuant to federal regulations.[3]

MediCal in conjunction with its fiscal intermediary, Computer Services Corporation, and with suppliers, establishes four digit billing codes and maximum allowances for items billed to each of these codes listed in the California Administrative Code. These codes serve as access routes for reimbursement. MediCal is a "direct vendor" program. Vendors (suppliers) submit claims directly to MediCal and MediCal pays them, not the beneficiary. Prior approval is required for all items costing over twenty-five dollars. So, in the case of DME, reimbursement is not a passive mechanism of payment for health services already rendered. Rather it is a primary actor in determining which technologies are reimbursed, and therefore, which technological innovations are diffused and utilized [4][2].

DME reimbursement is based on Scheduled Maximum Allowances (SMAs). The SMAs are determined by MediCal Rate Development in conjunction with suppliers. The procedure that MediCal uses to determine these maximum allowances for listed DME will be discussed. The decision to rent or purchase the equipment is made by MediCal (in conjuction with the supplier) based upon the physician's prescription. Listed items have scheduled maximum allowances (SMA) while claims for unlisted and some listed items must be submitted "By Report"[6][7].

In addition to other required information, billings for equipment reimbursed "By Report", whether listed or unlisted, shall include or be accompanied by a description of the equipment indicating: (1)The manufacturer's name and suggested retail price for the equipment. (2)Description of and justification for any special features of the equipment such as custom modifications or special accessories. (3)If an unlisted item, the reason a listed item cannot be used.[3]

All beneficiaries must have a physician's prescription before they can obtain any DME. This prescription must include: (a)diagnosis of patient's condition, (b)prognosis of patient's condition, (c)reason for prescribing the equipment, (d)explicit justification for custom features, and (e)estimate of the number of months the equipment is needed. "Carefully detailed physician prescriptions may, and have, assured funding... However, the actual matching of DME to the patient's needs is often done by providers such as social service workers, visiting nurses, orthotics specialists, and others who transmit the pertinent information to the prescribing physician."[6] This prescription establishes the case for "medical necessity" which is the primary criterion for reimbursement of DME. "Lack of proof of medical necessity is often a reason for denial of funding even if the services are necessary for the comfort or convenience of the patient."[6] MediCal employs "Consultants" (physicians) to determine the validity and the medical necessity of claims. These consultants, however, "rarely have experience with rehabilitation and do not fully understand its function."[6]

While Rate Development determines the amount to be reimbursed for DME, MediCal Benefits determines what will be covered. MediCal coverage for new, 'experimental' devices does occur intermittently [1]. The precise procedure is not clear as individual cases are handled on an individual basis. "A technology is perceived to have moved beyond experimental status to clinical application, and to be accepted by the local medical community, is considered 'reasonable and necessary' and thus is covered, if it is not specifically excluded from coverage." [6]

Physicians as Gatekeepers

Physician knowledge of rehabilitation and rehabilitation technology is a critical element for the patient's acquisition of wheelchairs and other DME. More research, particularly quantitative research, is needed to better understand the physician's role in DME reimbursement process. [1]

There is also often a communication gap between health care personnel and engineering designers and developers which slows the development of new and appropriate products. This is partly the result of different frameworks for categorizing lost/impaired function. The medical profession generally maintains more of a disease orientation for their categories (for instance, multiple sclerosis or cerebral palsy) and the engineering profession more of a functional loss focus (such as mobility, or communication). Mutual education is required [9][48]. Engineers must understand the clinical factors which impact on the use of assistive devices and physicians need to understand more about the role of assistive devices in rehabilitation.

Recommendations

Physicians and engineers can be better informed about rehabilitation and use of rehabilitation technologies in the following ways: (1)Increased emphasis on rehabilitation and introduction to the uses of rehabilitation technologies during medical school training is especially important to future physicians who will be treating increasing numbers of persons of all ages with disabilites. (2)Seminars/Workshops at professional conferences on rehabilitation and rehabilitation technologies will enable physicians to obtain continuing education credits for studying rehabilitation topics. The same could hold for engineers studying human biology topics. (3)Physicians and engineers must be encouraged to use ABLEDATA in order to gain a better knowledge of what is available to assist patients with temporary or permanent physical disabilities. This might be achieved through advertisements in professional journals and exhibits at professional conferences. (4)Development of a rehabilitation technology reference service analagous to existing pharmaceutical reference services would assist physicians in their information quests. (5)Scheduling of rehabilitation engineering professional meetings in conjunction with other medical professional conferences (such as A.M.A.) will increase information transfer.

In conclusion, the role of third party reimbursement in the diffusion of rehabilitation innovations must be researched from multidisciplinary viewpoints if users are to realize the benefits of rehabilitation research and development.

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THIRD PARTY REIMBURSEMENT AND THE DIFFUSION OF REHABILITATION TECHNOLOGY

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ABSTRACT - Third Party reimbursement procedures often determine which technologies users actually acquire. These reimbursement mechanisms, however, are generally inadequate to address the rehabilitation technology needs of many citizens.

RÉSUMÉ - Les mècanismes de remboursement par un tier servent souvent à déterminer les appareillages que les usagers achètent réellement. Ces mécanismes sont généralement déficients pour ce qui est de faire connaître les besoins en appareillage de réadaptation de nombreux citoyens.

Introduction

The Office of Technology Assessment concludes:

> ...that new applications of existing technologies are not adequately identified for assessment. To facilitate identification of such technologies, the most promising approach may be the use of the reimbursement system to link the diagnosis with the use of the technology.[6]

The current third party reimbursement system plays a major role in the acquistion of rehabilitation technology [1]. Most rehabilitation technology is reimbursed under the category of durable medical equipment (DME). DME is reimbursed if it is "medically necessary." This medical necessity is determined by physician prescription and validated by physician "consultants" hired by the reimbursers. Most (if not all) reimbursers have some form of an 'approved list' which documents what will be reimbursed and the amount paid per item. While these systems usually have a category for 'unlisted' items--allowing the opportunity for innovations to be reimbursed--, they lack the machinery to establish baseline information about the innovative uses of rehabilitation technologies. However, no data exist to analyze the types of innovations which are being reimbursed because of the current record keeping systems. This has occurred because information about all unlisted equipment is usually stored in one combined category, and therefore, no records exist to indicate which innovations, if any, are being funded. In addition, if it is kept, it is proprietary and generally unavailable for analysis. (This is also true of Medicare reimbursement because proprietary fiscal intermediaries administer the Medicare program.)

The Problem

One major effect of the particular DME classification method described above, is that knowledge transfer about innovations cannot occur because no accessible records are kept on particular devices that have been funded. If an innovative technology is prescribed and reimbursed for a particular case, no retrievable systematic evidence exists of this "match" between technology and user. As a result, awareness of new technology and its appropriate application is reduced. Side effects include: a)expensive duplication of effort which, in turn, reduces the efficiency of rehabilitation research and development, and b)no systematic means for determining the success of the innovation, or criteria for that success, over time.

Additionally, the approval requirements for unlisted items, demand more effort by the prescribing physician and DME supplier to write up the justifications. Since no special form or specific guidelines exist, this "creative writing" task may become a disincentive.

The additional requirements for unlisted items may further slow the rate at which DME users obtain the device by reducing the number/amount of claims that reach the final stage. This may be desirable from the medical point of view if the bureaucratic process serves as a deterrent to claimants with marginal, optional, or fraudulent claims.

The case of wheelchairs illustrates a related problem. The scheduled maximum (dollar) allowances (SMAs) for reimbursement of wheelchairs and accessories are usually still inadequate, according to Peter Axelson, member of the RESNA's wheelchair standards committee [2]. Potentially higher quality, more durable items are generally more expensive and can only be reimbursed through the unlisted categorization because the SMA for the listed item is too low. (This is more likely to be true in expensive items such as a wheelchair or wheelchair accessories rather than with a cane.) If this more expensive item does, indeed, prove to be superior in certain cases, that information is lost to other claimants and funding sources. We suggest compilation of and access to indexed lists of the "unlisted items" reimbursed and their medical justification. This systematic documentation could facilitate the diffusion of innnovative devices by educating physicians and engineers as to possible uses of new technologies.

Expansion of Need Beyond Medical Necessity

At the present time, rehabilitation technologies are reimbursed only if they are "medically necessary" and are mandated by a prescription. Determination of medical necessity is dependent on the persuasiveness of the prescription [7]. Power for decisions regarding reimbursment is vested in an extremely small number of people who often have little or no engineering background. In addition to the medical expertise already established in the process, engineering expertise must be explicitly incorporated into the reimbursement decision-making process by requiring it to be a qualification for the DME MediCal consultant or analyst position. This multidisciplinary approach becomes increasingly important as technologies and their applications become more complex [4][3][5].

Recent research would indicate that serious consideration be given to alteration of the requirements for devices to include a broader definition in addition to medical necessity [3][1]. Third party reimbursement plays a pivotal role in impacting the quality of life of Americans. Perhaps in light of the recent technological advances, 'necessary for independence' or 'necessary for activities of daily living' might be more appropriate concepts. In this way, emerging rehabilitation technologies could be reimbursed and their impact on long term and acute care costs could be assessed. Functional classifications for reimbursment of rehabilitation technology at government levels, analogous to those set forth by ABLEDATA, might prove to be one means of facilitating a more complete reimbursement mechanism. The final report of a three year study conducted by the California Department of Rehabilitation, funded by the NIHR, stated that:

> ... it is necessary to understand how the rehabilitation process differs from the traditional medical process in dealing with the problems of the client or patient. In the rehabilitation process, the problems of the client are varied and occur in a variety of environments. These environments can include home, transportation to and from work or school, a work or school environment itself, recreational environments...The rehabilitation process examines each of these needs as they occur naturally within each specific environment as a part of a effort to develop a total integrated plan for the client to be able to return or for the first time become involved in the work force or in society in general. The medical process is one which focuses mostly on the individual regardless of the environment...[3]

The traditional physician is less concerned with the person/environment interaction. The rehabilitation professional must be primarily concerned with the individual/environment interface in a range of settings. From a long-term perspective, cost-effectiveness of DME must therefore be based on that same broad range of need. 'Medical necessity' is insufficient to address the spectrum of needs of people with disabilities. Therefore, the criteria for provision of DME should be expanded to include "necessary for daily living" or "necessary to maximize independence" in order to address the multifaceted needs of persons of all ages with disabilities.

State rehabilitation nurses, or designated home health agency nurses might certify DME need much like the physician certifies medical need with prescription for DME which is "medically necessary." Such an expanded system would maintain the physician as prescriber of DME for medical need and rehabilitation nurses (or other rehabilitation professionals) as certifiers of rehabilitative, nonmedical need.

The mandate for a broader definition has been intensified as a result of technological advances that have yielded products necessary for independent daily living but not traditionally thought of as "medically necessary". One example is 'environmental controls'. These devices might be essential to a severely disabled person's ability to remain at home and out of an institution. Yet, Medicare, for example, does not reimburse environmental controls because they are not 'medically necessary.'

Summary of Recommendations

1)Improve physician knowledge of rehabilitation and the uses of rehabilitation technologies,

2)Explicitly include engineers in the DME reimbursement decision-making process along with physicians,

3)Reclassify 'Unlisted' DME items into functional categories so that diffusion and utilization of rehabilitation innovations can be tracked,

4)Expand need requirement to include "necessary for daily living" or "necessary for as much independence as possible,"

5)Study the issue further. An agenda for suggested future research will be discussed.

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ÉVALUATION DES RISQUES À LA SANTÉ RENCONTRES DANS L'ENVIRONNEMENT DE TRAVAIL DES ERGOTHÉRAPEUTES

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RÉSUMÉ - Cette communication fait la revue des risques à la santé encourus par les ergothérapeutes en milieu de travail. Les auteurs veulent mettre l'accent sur l'éducation des thérapeutes sur les risques à la santé dans l'accomplissement de leur travail quotidien. Certaines mesures correctives sont aussi présentées.

ABSTRACT - This paper reviews the health hazards encountered by the occupational therapists in their work environment. The authors want to emphasize the need to educate the therapists of the health risks involved in the day to day work. Some corrective measures will also be presented.

On peut définir l'ergothérapie de la manière suivante:

> "(...)l'application du travail et de son effet sur tout être humain pour faciliter l'intégration des aspects biologique, social et psychologique de l'individu vers un fonctionnement optimal(...)"[1]

Au sens le plus large de cette définition, le travail devrait amener tout individu au sommet de ces capacités physiques et mentales. Malheureusement, en ergothérapie, le bien-être du patient nuit très souvent à celui du thérapeute menant à une diminution des capacités de ce dernier. C'est pour cette raison et à cause du manque d'information sur le sujet[2], que nous avons décidé de nous pencher sur le problème de la santé et sécurité dans le domaine de l'ergothérapie.

La méthodologie que nous avons employée est des plus simple. Elle est axée principalement sur l'identification rigoureuse des facteurs d'agressions. Deux approches majeures ont été utilisées en vue de cette identification:

- visites des lieux de travail;
- recherches bibliographiques.

Les visites des lieux de travail nous ont permis d'identifier, que nous l'espérions, trois catégories principales de risques: biologique, chimique et physique. Les recherches bibliographiques nous ont apportés plusieurs détails associés à chacun de ces facteurs.

En milieu clinique, l'ergothérapeute est appelé à travailler dans divers services et à cotoyer toutes sortes de patients. Bien que de nos jours les conditions d'asepsie soient bien controlées, le thérapeute doit souvent travailler avec des patients ayant des plaies ouvertes et purulentes. Les infections bactériologiques et/ou virales découlant de ce contact ne sont pas rares bien que très souvent les causes en soient inconnues ou ignorées. Les types d'infections suivants sont les plus susceptibles d'être rencontrés chez les ergothérapeutes: l'hépatite virale, le tétanos et la tuberculose[3]. De même que les infirmier(e)s et les médecins, les thérapeutes sont aussi susceptibles d'attraper toutes les sortes de maladies contagieuses que l'on retrouvent à l'intérieur d'un hôpital.

Les risques chimiques sont sans doutes les plus méconnus parmis les ergothérapeutes. Nous pouvons les classifier en deux catégories arbitraires: les agents directs (e.i. les solvants ou les poussières) et les agents indirects (e.i. les produits de décomposition thermique de certains plastiques). La majorité des expositions à ces polluants provient d'une pratique de travail inadéquate et dont nous discuterons l'aspect correctif un peu plus loin.

Plusieurs solvants sont employés lors de la fabrication et l'ajustement des orthèses. Les plus fréquents sont l'acétone, l'éther diéthylique, le chlorure de méthylène, la térébenthine et le trichloro-1,1,2 éthylène. Ces différents produits chimiques sont susceptibles de causer l'irritation des voies respiratoires supérieures et des yeux, une dépression du système nerveux central (charactérisée par des céphalées, des étourdissements, des nausées et pouvant mener au coma) et des dermatoses. Dans la pratique, les "laboratoires" où les travaux d'orthèses sont effectués ne comportent pas de systèmes de ventilation adéquats (des mesures de concentration seront présentées lors de la conférence). Un autre produit toxique est employé dans la fabrication d'aides-techniques. Il s'agit du diphenylméthane diisocyanate (MDI). Ce produit est un irritant très fort des voies respiratoires, de la peau et des yeux. Il peut, de plus, produire une réaction de type allergène.

Les poussières de plastiques et d'autres matériaux utilisés pour la fabrication d'orthèses sont généralement oubliées comme risques potentiels. Bien que souvent de diamètre supérieur à celui considéré comme dangereux pour la santé (inférieur à 5 um), ces poussières peuvent causer l'irritation du nez et des yeux allant quelquefois jusqu'à des lésions plus graves. De plus, les travaux de finition (ponçage et polissage) émettent de fines poussières susceptibles de causer l'irritation des voies respiratoires inférieures. Là encore une ventilation adéquate et l'éducation des thérapeutes sont des mesures essentielles à leur protection.

La partie la plus importante de nos travaux porte sur la décomposition thermique des matériaux servant à façonner les orthèses. La plupart de ces matériaux sont des polymères thermoplastiques (polymères susceptibles d'être "refondus" plusieurs fois sans subir aucune altération dans sa forme et sa composition) qui ne présente pas de toxicité propre[4]. Par contre, un risque de lésions cutanées (e.i. érythème localisé et dermatite de contact) peut provenir du contact répété avec certains matériaux. Les principaux types de polymères employés sont les polyéthylènes et polypropylènes, le polyisoprène, le styrène-butadiène, le méthacrylate de méthyle, les mousses de polyester et le polychloroprène. La plupart de ces produits sont vendus sous marques de commerces et contiennent généralement divers types d'adjuvents qui varient selon les propriétés physiques et mécaniques désirées. Ils sont généralement accompagnés de fiches d'instructions décrivant les diverses propriétés physico-chimiques et mécaniques nécessaires à leur utilisation. Ces instructions contiennent presque toujours une "température recommandée d'utilisation" qui, malheureusement, n'est pratiquement jamais respectée par les thérapeutes. C'est à ce moment là que les risques à la santé se manifestent.

Plusieurs sources de chaleur sont utilisées pour ramollir les polymères, allant du bain de vapeur d'eau (température entre 45 et 100°C) jusqu'au "fusil" à air chaud (température pouvant aller jusqu'à 400°C). Dans les "laboratoires" de fabrication d'orthèses, certains fours conçus expressement pour ce type de travail et possèdant un contrôle variable de température sont en opération. A cause de certains facteurs qui seront décris en détail lors de la présentation (e.i. temps, espace et conditions de travail, mauvaise "éducation"), les températures recommandées ne sont pas toujours respectées. Cette pratique peut alors causer l'émission de gaz plus ou moins toxiques allant du monoxyde et dioxyde de carbone jusqu'au phosgène (des mesures de concentration seront présentées lors de la conférence)[5,6,7].

Les maux de dos dus à de mauvaises postures représentent le risque de dommages physiques le plus fréquent. La possibilité de blessures aux membres supérieurs et aux yeux n'est pas à exclure durant la fabrication et l'ajustement d'aides-techniques (e.i. découpage, ponçage). Les brulûres sont aussi courantes lors de la fabrication d'orthèses.

Les programmes correctifs proposés pour les differents cas décris précédemment ont pour base principalement l'éducation des ergothérapeutes et autres professionnel(le)s faisant le même genre de travail. Afin de réduire les pratiques de travail dangereuses, ces professionnel(le)s devraient être à même de savoir identifier les risques qu'ils encourent. Cette éducation devrait se faire au niveau des établissements d'enseignement afin que les principes de sécurité deviennent un "réflexe" pour le thérapeute. Si cette ressource n'est pas disponible, la sensibilisation à l'intérieur du département d'ergothérapie ou par l'intermédiaire du comité de santé et sécurité au travail est à souhaiter. Le deuxième élément correctif est l'adaption physique du département d'ergothérapie en fonction des besoins et non pas l'adaptation des besoins en fonction des locaux (e.i. dessiner un système de ventilation adéquat, réserver certaines surfaces de travail pour le moulage et d'autres pour le collage). Le dernier, mais non le moindre des éléments correctifs, est la protection personnelle du thérapeute qui devient essentielle dans certaines situations (e.i. gants et masques de chirurgie dans les cas de patients "contagieux", gants de caoutchouc, lunettes de sécurité et masque à "gaz" pour certain solvants, gants d'amiante pour le travail avec des sources de chaleurs).

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REALIZING THE POTENTIAL: DISABLED ADULTS USING MICROCOMPUTERS

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ABSTRACT - The Ontario March of Dimes is undertaking a service-oriented project investigating methods of making microcomputers available to severely disabled adults in such a way that the computer serves a lasting and useful function. Various issues related to the cost, functional requirements and evaluation of microcomputer service programmes are discussed.

RÉSUMÉ - L'Ontario March of Dimes mène une enquête sur des méthodes permettant d'offrir des services durables et utiles de microinformatique aux adultes gravement handicapés. Divers problèmes touchant le coût, les conditions de fonctionnement et l'évaluation de ces services sont abordés.

In 1981 the Ontario March of Dimes started a programme to distribute and support environmental aids for the adult disabled population of Ontario. This was an extension of the long standing Assistive Devices Programme which provides wheelchairs, driving aids, prosthetics, orthotics and home improvements. Recently, based on the number of disabled individuals and rehabilitation organizations inquiring about inexpensive home microcomputers, the Ontario March of Dimes realized that there was a need for a new service programme dealing with microcomputer-based technology.

How can these computers be best utilized by the disabled population? Using the existing service delivery structure, how can the computer be integrated into an individual's lifestyle in such a way that appropriate and lasting use of microcomputer technology is ensured? It was these questions which prompted the development of the pilot microcomputer project.

The project was designed to specifically address these questions:

1. Which microcomputer activities are of particular interest to disabled adults and how can these activities influence their lifestyles?
2. What sorts of adaptations are required to give the disabled individual access to the microcomputer? Which microcomputers are best suited to the different kinds of adaptations? Which commercially available adaptations are appropriate in which situations?
3. How much support time (therapist, teacher, technician) is needed to set up one individual with the microcomputer? How much continuing support is necessary?
4. How does one evaluate the effectiveness of a service programme such as this?
5. What are the costs of providing hardware, technical and administrative support for this kind of programme?

With the above questions in mind, the microcomputer project was developed. The project goal is to distribute and support microcomputer systems in four Ontario locations for use by severely disabled adults. Individuals involved in the project will be encouraged to use the microcomputer independently for personal communication, record keeping and recreation. Project staff and volunteers will support these individuals and encourage them to explore a wide range of activities.

Specific project objectives are:

1. To explore and implement techniques for evaluating the impact that microcomputer-related activities can have on severely disabled adults.
2. To field test different kinds of microcomputer hardware and software to determine which configurations are popular and appropriate for different populations.
3. To determine the future role of the March of Dimes in microcomputer-related programmes. This should include an indication of the time, staff and financial requirements of providing this service.
4. To provide some technical support for other groups who already have equipment and are interested in co-ordinating a similar programme.
5. To create a library resource providing information on microcomputer related subjects to the regional March of Dimes offices.

To co-ordinate this project, one full-time staff member was hired. A volunteer committee was formed. It consists of rehabilitation specialists (speech pathologist, educator, rehabilitation engineers), community volunteers, and March of Dimes research support staff. The committee is responsible for selecting appropriate settings for the project computers, and with the development of appropriate evaluation models. The staff co-ordinator is responsible for: the purchase of appropriate hardware and software, installation and maintenance of equipment, and ensuring each individual has an appropriate means of accessing the computer.

The site selected for the project will likely be a residential setting. The project participant will be chosen with the help of the therapy and administrative staff at the institution. Other residents and staff members will also be encouraged to make use of the project microcomputer.

The project specifies that a small service oriented environment is to be created in a chronic care setting. This will be done in at least four different locations over a period of two years. The first site will be monitored for 18 months and the last site will exist for at least 9 months. At each location, 3 or 4 individuals will formally participate in the project.

Individuals involved in the project will have had little or no previous microcomputer experience. They will be introduced to the microcomputer through activities such as word processing for personal use, and recreational software such as music and drawing programs. Activities will be chosen on an individual basis depending on the interests of the participant. Volunteers will work with each participant to introduce them to a wide range of activities.

Success will be measured in terms of indiyidual improvements and sustained interest in the programme. Because individuals with similar physical limitations will be chosen, generalized conclusions about providing support to a particular population will be possible.

When this paper is presented, the first installation of the March of Dimes microcomputer project will be five months old and the second will be newly underway. Experience gathered from the installations will be presented along with evaluation models with actual data from the first installation.

This project is funded by the Trillium Foundation and the Ontario March of Dimes.

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Michael Berman is a lawyer and part-time consultant with the project.

MICROCOMPUTER APPLICATIONS

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ABSTRACT - This presentation describes technical aids services aimed at upgrading the quality of life of disabled persons. There is an emphasis on the microcomputer applications program implemented at Mackay Center.

RÉSUMÉ - L'objectif de cette présentation est de décrire un type de services d'aide technique instauré en vue d'améliorer la qualité de vie des personnes handicapées. Le programme d'applications micro-informatiques y est souligné de façon particulière.

The Mackay Center Technical Aids Program aims at improving the independence of our pediatric population. This program contributes to the betterment of the quality of life of the disabled person through recommendations of technical aids. It covers needs at home for architectural barriers, high and low technology adaptations of all kinds as well as their maintenance and repairs. There is also a data base on provincial resources including services and technical aids available through centers and special equipment companies in Québec.

The Technical Aids Program is divided into three activity levels. First, in an attempt to reduce costs, commercially available products are recommended. These products are reliable and their price is quite low. This approach seems to serve a good percentage of our disabled population. Added to the low cost, reliability and availability, advantages are optimal because no modification and reduced maintenance are required.

To attain this, a small local data base helps us in the decision-making process to recommend technical aids. The importance of a good information system cannot be stressed enough and sometimes we use larger national data base systems.

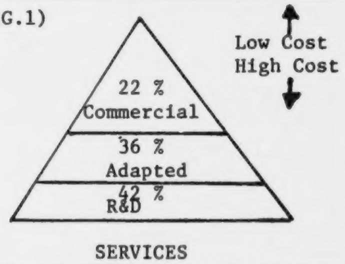
When the first approach is insufficient, an alternative is to adapt commercially available products. Advantages are low cost of products and reliability. Disadvantages are the cost of manpower and materials needed to adapt the commercial products. However, these costs are still reasonable.

The third level of activity is really the last resource we look for. In fact, in this approach, we are back at square one and we must design the technical aid that never "existed" before. Often, one can find "existing" prototypes of technical aids with a good information system. These prototypes can be found in rehabilitation facilities in your own province sometimes.

This is the rationale behind an information system that allows a better management of technical aids research and development projects. We must keep a link with other centers to have a clear understanding of present technical aids research projects. This philosophy will prevent us from "re-inventing the wheel".

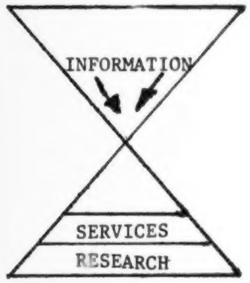
From this global approach, we can design a concept of intervention (fig.1). There is a direct correlation between the base of each inside part of the triangle and the cost of related services.

(FIG.1)



A second large triangle (fig.2) is the symbol of the information system. This system shows a convergence of information. The gathering of information and better, its organisation and dissemination helps to answer the disabled person's needs. When specific information is finally collected, it is directly associated with area no. 1 of the services triangle for purchasing, with area no.2 for adaptation and with area no. 3 for development if needed.

(FIG.2)



When implementing a microcomputer applications program (1), one must consider all these facts and follow some principles. These will ease the microcomputer applications process with the disabled person.

There is a close relationship between high and low technology in technical aids concepts even though their morphology is different. The main objective is to answer optimally needs ot the disabled population. The access to high and low technology by disabled individuals, in a socio-economic perspective, has always been a policy of the Mackay Center. This simply means that financial considerations in the provision of technical aids is as important as is the technology itself.

Also, technical aids should allow as much as possible a freedom of choice and movement. The portability aspect of any aid is a must if integration is considered. Simplicity of use is most significant because it grants a larger access to disabled persons. These principles are used in the implementation of our microcomputer applications program..

We use commercial products such as voice synthesizers, special software(2) and hardware (3) to adapt easily our microcomputers. Commercially available microcomputers such as the Apple IIe have been modified with our own keyguards and special switches to allow an access denied because of a lack of availability of commercial equipment at the time and also because of the high cost.

Among other things, we have bought less expensive equipment such as the portable Timex-Sinclair microcomputer. This is a rather small computer but the cost, portability and simplicity characteristics have provided a larger accessibility. A unique switch can control this microcomputer and several different communication codes can be supported.

Multiple combinations such as environmental controls through a wireless telephone line coupled with modems, are possible and infinite. The same can be done with remote controls as well. This fact gives us several alternatives in the selection of specific adapted equipment for the disabled person. A simple software that can be modified as needed is used as main support for this approach.

Some basic ideas have been presented. However, even if high technology is increasing in our daily life, we must not take it for granted in the case of the disabled. Such examples as the telephone, radio or even television were accessible to the disabled in a relatively easy way only for the last few years.

This is why our use of the present and future technology has to be supported by an understanding of fundamental approaches that is more important than just recommending technical aids without any supportive philosophy behind services and research. We must help the disabled persons to abandon the status of passivity due to the lack of access means. We must give them the opportunity to an enriched participation to the socio-economic life.

We have to keep an individual approach and be flexible. This could be called the quality of services and leads to progress of the quality of life of everyone.

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PROMOTION OF OPTIMUM FUNCTION IN HANDICAPPED PEOPLE -- THE ROLE OF A REHABILITATION ENGINEERING SERVICE CENTER (RESC) AS A REGIONAL RESOURCE

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ABSTRACT - The Rehabilitation Engineering Center (REC), Children's Hospital at Stanford (CH@S) is described as a valuable regional resource in Northern California. Over 1000 clients a year are seen, including 40% adults, with two-thirds of referral from outside CH@S. Four additional proposed ways to increase the REC's value to the community are described.

RÉSUMÉ - On décrit le Rehabilitation Engineering Center (REC) du Children's Hospital de Stanford (CH@S) comme une précieuse ressource régionale du nord de la Californie. On y voit plus de 1000 clients par année, y compris 40% d'adultes. Deux tiers des clients viennent d'ailleurs que du CH@S. On décrit quatre nouvelles propositions destinées à accroître la valeur du REC pour la communauté.

The Rehabilitation Engineering Center (REC), Children's Hospital at Stanford (CH@S), was opened in 1974, adjacent to the 60-bed CH@S, which serves as a tertiary referral center for children with chronic handicapping conditions, including neurological and orthopedic impairments.

Referrals are made to the REC from this hospital and from the geographic area of Northern California, with a population of approximately seven million. The range of service provision at the REC includes prosthetics, orthotics, seating and mobility devices, communication aids, and various combinations of equipment for the multiply handicapped. A Child Prosthetic Clinic has been in operation since 1976 and a Rehabilitation Engineering Clinic was started in 1981.

There are advantages to a location near a hospital-medical center. Among these are easy access to medical personnel, occupational and physical therapists, and laboratory facilities such as EMG, EEG and X-ray, and a "Gait Lab" for movement measurements and assessment.

The first several years of the REC's development were spent in organizing the delivery of comprehensive patient services, primarily for CH@S patients. Since that time, the REC has grown to be a regional resource for rehabilitation engineering services in Northern California. The REC currently serves over 1000 clients a year, with an average of two to three visits per client. Estimations for 1983 show that 40% of the total are adults and two-thirds are referred from physicians and community sources outside the hospital.

The orthotics service recorded 1242 patient visits in 1982-83. Orthoses delivered included upper-limb, lower-limb and spinal orthoses, custom cuirasses, and biofeedback orthoses. The prosthetics service recorded 887 visits in 1982-83. Patients of all ages and all reasons for amputation were seen, and prostheses included lower-limb, upper-limb, standard and specially fabricated devices, as well as equipment which required prosthetic technology in construction.

In communication and controls, assessment and provision of communication aids for people who are non-speaking and/or non-writing, as well as controls for communication, mobility, and environmental systems were provided. This service has a comprehensive selection of communication aids and controls for display, demonstration and assessment. Thirty seven clients were assessed for a variety of controls and assistive devices. In addition, the communications and control engineer visited 10 schools in the area to demonstrate devices and provide consultation to teachers.

The service for prevention of tissue trauma also provides assessment and recommendations for customized systems to diminish or redistribute pressure-sore-producing forces for asensory individuals, usually with para- or quadriplegia. Thorough evaluation of the skin and sitting positions is done prior to recommendation for technical assistance. 108 client visits were reported in 1982-83.

A service called "Special Devices" is involved in assessment and provision of aids for proper body positioning and mobility assistance. It has a large selection of mobility aids for display, demonstration and assessment with clients. These aids include seating systems, manual and powered wheelchairs, lap trays and special accessories for wheelchairs and other aids for ambulation or body support. 461 client visits were recorded in 1982-83.

The Child Prosthetic Clinic met six times at bimonthly intervals and carries a roster of 45-50 children, aged three months to 21 years. It is the California Children Services (CCS) approved center for Northern California. The Rehabilitation Engineering Clinic recorded 99 visits for assessment and recommendations for assistive devices in 1982-83.

When a client is referred to the REC for an assistive device, functional assessment is emphasized by a team consisting of an engineer, an occupational therapist and the client and family, with physicians, social workers, speech and/or physical therapists available as needed. In deciding what assistive equipment is to be provided, the team must analyze the patient and define the treatment goals. The analysis includes an evaluation of the client's functional limitations and capabilities, the environment in home and community in which activities will be performed, and the resources available for assistance. Resources include support and training personnel, as well as environmental and financial assets. The goals include improvement in functional performance related to education, safety, employment, social interaction and activities of daily living.

Functional assessment is usually divided into four areas: communication, mobility, fine motor (hand use) and understanding. Sensory impairments in vision,hearing and touch must be considered, and the presence of alterations in mental function associated with seizures, emotional or behavioral disorders. The possible availability and effectiveness of training in use of the assistive equipment must be taken into account. In addition, the team must be aware of physicians' recommendations regarding surgery, medication and therapy which may affect use of assistive devices.

The REC is very fortunate in having on-site a rehabilitation counselor from the State Department of Rehabilitation, who staffs an information and referral service and has access to ABLEDATA, a service of the National Rehabilitation Information Center. An interchange of information between this counselor and the REC staff is of great benefit to all personnel.

In summary, rehabilitation engineering services were provided in a total of 2827 visits in 1982-83. These services are geared toward improving functional levels, after careful assessment, inquiry into available resources and with cooperation and consultation of clients and their families. Handicapped children and adults are increasingly aware of the benefits of technology, but are often uncertain which devices will help them and where to find those of greatest usefulness. A center, of the type described above, can be a very valuable resource to the community.

Looking to the future, there are four ways in which a Rehabilitation Engineering Service Center (RESC) can be increasingly helpful to the community of the handicapped:

1. A demonstration living center is one means of assisting clients in making choices appropriate to their needs. Providing an opportunity to try out, look at or hear about a variety of devices would expand the usefulness of a center in serving the disabled population and their families, as well as allowing feedback from this group to the service providers.

2. Consultation services to schools, developmental disabilities centers and independent living centers should be a part of the "outreach" potential of an RESC. A mobile unit which can go to these facilities, with appropriate personnel to assess and evaluate children and adults where they live, work or attend school, would assist in the solution of problems which cannot be completely anticipated when the client comes to the center. Decisions about the training of personnel in use of assistive aids, and integration of these aids into educational or work programs, can also be a useful service of the rehabilitation engineering consultants.

3. To increase and round out the services of an RESC, it is important to foster an interlocking partnership with other professional suppliers of durable medical equipment and assistive aids. Each has a role to play for the benefit of the client and family, and a comfortable working relationship among all suppliers is of value to everyone. When commercially available devices are less expensive and equally suitable for the client, the center recommends these and tells clients and their families where to find them. Hopefully, suppliers will be equally willing to refer clients when no off-the-shelf item will serve their needs, or where substantial modifications will be required.

4. Finally, continuous effort needs to be made to educate funding agencies and the community-at-large, including educators and employers, in the value of assistive aids in complementing the abilities of the handicapped. Cost/benefit in terms of productivity, reduced support services and increased client satisfaction must be documented and disseminated widely. By keeping careful records of costs and outcome benefits, a regional RESC can make a substantial contribution to better living for the disabled community.

A TECHNICAL AIDS SERVICE DELIVERY PROGRAM IN BRITISH COLUMBIA, CANADA

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ABSTRACT - This paper describes a technical aids program serving severely physically disabled residents of British Columbia. It contains an outline of the main service delivery components and how they are presently implemented.

RÉSUMÉ - Cette communication décrit le programme d'aides techniques mis sur pied en Colombie-Britannique pour desservir les citoyens gravement handicapés physiquement. On décrit les principaux éléments de la prestation du service et on indique comment ils sont actuellement mis en oeuvre.

INTRODUCTION

In early 1972 the Kinsmen Rehabilitation Foundation of B.C. initiated a program to research availability of technical systems designed to bring some measure of independence to the severely physically disabled, including those who had lost speech as well as physical functions.

The first installation (POSSUM) (1) was made in September 1973 in Richmond, B.C., followed by a second system (GENIE) (2) in West Vancouver within a month. After a ten year period the Technical Aids Program has supplied services to 559 clients. The current active client list totals 309. 191 clients are presently using environmental control, 92 are using communication systems and 26 are using a combination of both.

The program assists individuals with physical disabilities resulting from High Level Quadraplegia, Cerebral Palsy, Multiple Sclerosis, Amyotrophic Lateral Sclerosis, Muscular Dystrophy, Rheumatoid Arthritis, Post Polio, Head Injuries and others.

Locations for technical aids systems include client homes, nursing homes, group homes, schools, rehabilitation units, and extended care and acute care centres.

All services of the Technical Aids Program are presently implemented by a staff composed of an Occupational Therapist and two Biomedical Electronic Technologists. Requests for technical aids service originate from various areas of the province of British Columbia. Staff travels to these areas as the demands require.

The Technical Aids program itself consists of a client service and a workshop area. The client service area provides for client information processing, client contact and case conferencing. It also serves as a technical aids display location for inhouse seminars and workshops. The workshop area, furnished with a selection of machine tools and electronic test equipment, allows for system development and equipment repair and testing. A technical aids vehicle, complete with a parts and supplies inventory, is also provided for maintenance and installation requirements.

DESCRIPTION OF SERVICES

The two major components of the program include Environmental Control Services and Communication Services. These services both provide:

1) APPLICATION AND REFERRAL - individual cases area studied in conference for possible service provision based upon submission of a Client Information Profile. Referral to other agencies or programs is provided if the client does not require Technical Aids Services.

2) ASSESSMENT - performed by Technical Aids staff along with client, family, and involved clinicians.

3) PROVISION OF SYSTEMS - includes familiarization, instruction, setup and installation of equipment.

4) TEMPORARY LOANS - equipment loans provided for assessment purposes. Clients may have to work with various aids until the appropriate system is found.

5) FOLLOWUP - determining system suitability, understanding, and use with a view towards possible upgrading or exchange.

6) MAINTENANCE AND REPAIR - providing assistance to clients in the event of equipment malfunction.

7) FUNDING - (for the program) is provided through the annual Kinsmen Mothers' March Campaign. The equipment is provided to the client on a permanent loan basis. Efforts have been made in the past year to retrieve funding for individuals from other agencies and government departments where applicable.

ENVIRONMENTAL CONTROL SERVICES - primarily deals with providing severly disabled persons with methods of access to standard equipment in their environments. Standard equipment normally refers to appliances such as intercom and doorlocks, telephones, television and radio, bed control, lights, tape recorders and call and alert systems. Environmental control services include:

1) provision and installation of environmental control systems enabling control of stand alone appliances (i.e. door lock and intercom controls only), 2 to 5 appliances (i.e. ENCO V system) (3) 5 or more appliances (i.e. TOSC II system) (4).

2) adaption and modification of clients' existing hardware for easier access (i.e. remote control t.v. or telephone)

3) computer access and control (i.e. expanded keyboard or keyboard interface).

4) modification or adaption of wheelchair controls where the present commercially available control is inaccessible to the client.

5) toy interfacing and adaption for switch activation.

6) consultation and public education.

COMMUNICATION SERVICES - deals with assisting clients and clinicians in determining needs for augmentative communication systems. These services include:

1) provision of communication aids such as word or symbol boards, portable communicators, scanning communicators, synthetic speech devices, and computer communication systems.

2) supplying and mounting hardware and control switches for communicator access.

3) consultation and public education including organization of seminars and workshops.

EDUCATIONAL ROLE

A major responsibility of a program of this nature is to continuously provide education to professionals and the general public as to the services available. With this in mind the program is involved in organizing workshops and seminars through colleges and schools, educational and rehabilitation groups, technical fairs, health agencies and disability groups.

The staff of the Technical Aids Department of the Kinsmen Rehabilitation Foundation have an expanded role in the education of Occupational Therapy students from the B.C. Institute of Technology. Practicums are accepted from both institutions. The Occupational Therapist of the department is now recognized as an honorary clinical instructor by the U.B.C. School of Rehabilitation Medicine.

CONCLUSION

It is important to mention that the services of the Technical Aids Department are highly dependent on assistance from professional teams, agencies, and volunteers. Therapists, teachers, clinicians and health professionals contribute greatly to the assessment and client training aspects of the program. Kinsmen Club members, B.C. Telephone Pioneers, and volunteer engineers and technicians help with equipment installations and equipment repair. It is through this assistance that the program continues to be successful throughout the province.

REFERENCES

(1) "Patient Operated Selector Mechanism" Aylesbury, Buckinghamshire, England.

(2) "Genie" - environmental control system - Seattle, Washington - no longer available.

(3) "ENCO V" - environmental control system - Technical Aids and Systems for the Handicapped, Toronto, Ontario.

(4) "Touch Operated Selector Control" - Technical Aids and Systems for the Handicapped", Toronto, Ontario.

SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 14

COMMUNICATION AIDS I - DESIGN AND EVALUATION/

AIDES À LA COMMUNICATION I - CONCEPTION ET ÉVALUATION

SIMPLICOM: UN TABLEAU BLISS ÉLECTRONIQUE

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RÉSUMÉ - Un tableau Bliss Électronique axé vers la personne handicapée, que l'on transporte avec soi. Son micro-ordinateur est préprogrammé, pour usage général. Il offre aussi la possibilité de s'adapter aux besoins spécifiques.

ABSTRACT - An Electronic Blissboard, made transportable outside, with and software turned on the cerebral palsy. The built-in micro computer is preprogrammed for general purposes, but can be programmed for specific needs.

INTRODUCTION

Il s'agit d'une table de communication pour personnes atteintes de paralysie cérébrale. En se servant d'un langage symbolique (Bliss ou autre), l'usager communique avec autrui via l'aide d'un micro-ordinateur intégré. Différentes façons de sélectionner un symbole sont offertes et ce avec différents types d'interfaces. De par sa légèreté, sa transportabilité et son étanchéité à l'eau, il en découle un appareil autonome, utile dans la vie de tous les jours.

ASPECT MECANIQUE

"Simplicom" est la deuxième génération de table Bliss électronique. Plusieurs évaluations ont été faites, pour donner un produit axé vers la personne handicapée. Ses particularités qui la distinguent sont:

- Légère et robuste: construction plastifiée avec renforts métalliques.
- Transportable: utilisable sur fauteuil-roulant.
- Coins arrondis.
- Système de fixation universel: s'adapte à toutes les largeurs de fauteuil.
- A l'épreuve de l'eau: peut être utilisé à l'extérieur comme à l'intérieur.
- A l'épreuve des radiations des moteurs électriques.
- Tableau Bliss inclinable/haute intensité: aide à la vision du tableau.
- Ecran alpha-numérique double: retransmet, pour l'usager et l'interlocuteur les mots choisis. Cette option entraîne un usage soit "éducationnel", soit"conversationnel".
- Contrôlable par la tête, la main, les pieds, ou autre partie du corps, selon le type d'interface choisi.

La mécanique a été pensée pour l'utilité et l'autonomie de l'usager. Simplicom sert tous les jours. Droit ou incliné, il sert comme table pour manger et étudier ou pour communiquer.

ASPECT ELECTRONIQUE

L'aspect électronique a été axée, elle aussi vers la personne handicapée, souffrant de paralysie cérébrale.

- Utilise la source 12 volts du fauteuil roulant, non-polarisé.
- Protégé par fusible.
- L'allumage, la remise à zéro et le contrôle de l'ordinateur par un seul bouton "adapté".
- Modes de balayages adaptés.
    - ligne par ligne
    - Joystick
    - 5 modes peuvent être programmés selon les besoins spécifiques.
- Chaque case Bliss peut effectuer un effet spécial, de façon indépendante.
    - 8 sont préprogrammés
    - 8 programmés selon les besoins.

FACILITES

- Différentes vitesses de décalage, pour le tableau Bliss et l'affichage alphanumérique.
- Mode alphabet: centralise le décalage sur l'alphabet seulement.
- Sortie sérielle pour communication avec imprimante ou ordinateur, en option.

CONCLUSION

Il s'agit d'un appareil autonomne. Il peut être utilisé toute la journée. Bien des facilités sont offertes en équipement standard. Cependant, le logiciel est conçu de façon à s'adapter aisément aux besoins spécifiques de l'usager.

BLISSYMBOLICS: BLISS SKILLS - A DRILL AND PRACTICE PROGRAM FOR THE APPLE COMPUTER

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ABSTRACT - The BLISSYMBOLICS: BLISS SKILLS package was created to broaden the base of Computer Assisted Instructional programs in the area of Blissymbolics. The programs are designed to provide both the multihandicapped Blissymbol users and their instructors with a flexible and adaptable computer assisted instructional tool.

RÉSUMÉ - Le BLISSYMBOLICS: BLISS SKILLS est un progiciel qui a été créé avec l'intention d'élargir la base de programmes EAO qui utilisent la symbolique de Bliss. Ces programmes ont été conçus afin de mettre à la disposition aussi bien des usagers multihandicapés des symboles Bliss qu'à leurs instructeurs, un outil EAO souple et adaptable.

The BLISSYMBOLICS: BLISS SKILLS program is a software package that has been developed at the Vocational and Rehabilitation Research Institute to provide students with the opportunity to independently interact with learning materials. The significance of "independent interaction" becomes evident when one considers the target population of this program; specifically, students who are multihandicapped, with a speech deficit being the common disability. This program provides them with the opportunity to respond to questions posed by the computer (i.e. gross motor movements, fine motor movements, head movement, etc., are all appropriate input methods for this program), in a language they understand (i.e. Blissymbolics) and without the aid of an instructor. The software also provides the instructor with the ability to create a number of different types of drill and practice programs than can be individualized to meet the student's needs.

The development of the software occurred as a result of:

1. The limited availability of microcomputer software for instruction in the area of Blissymbolics, and,
2. The availability of the Minnesota Educational Computing Consortium's (M.E.C.C.) Blissymbolics software [1] that is written in the Basic computer language.

The BLISSYMBOLICS: BLISS SKILLS program allows an instructor with minimal exposure to the computer to:

1. Create Symbol Libraries
   A user library of Blissymbols chosen from the M.E.C.C. BLISSYMBOL: BLISS LIBRARY diskettes can be created and stored on the BLISSYMBOLICS: BLISS SKILLS data disk. As many as ninety Blissymbols may be stored in the computer's memory at once, for immediate access.
2. Create Blissymbol Drills
   Once a symbol library has been created, the instructor can then produce various drills from the symbols within this library. The instructor has four drill formats to choose from depending on the student's skill level, as well as the course material being instructed. The first format is the presentation of a single symbol match-to-sample with two choices in the sample. The second presentation has a single symbol match-to-sample with three choices. The third presentation is a two symbol matching drill with two choices. The fourth is a two symbol matching drill with three choices. The choices from which the student is to make the selection are presented on the screen to the right of the sample. A vertical line separates the screen into question and answer. A horizontal line separates the question/answer section of the screen from the area that has been designated for feedback. All feedback is given in Blissymbols, i.e. if the student's response is incorrect, the Blissymbol for "NO" appears in the bottom segment of the screen and the student is allowed to attempt the question again. If the student is correct, the phrase "YES GOOD WORK" appears in Blissymbols accompanied by an auditory "beep". The choices appear on the right side of the screen in a vertical orientation. The student makes his selection by waiting for an

arrow to be positioned adjacent to the appropriate symbol. The instructor determines and sets the amount of time the arrow is to remain beside each choice (i.e. time delay can be set from one to eighteen seconds). When the arrow is positioned, the student accesses any key or group of keys on the keyboard to register his answer. The program provides immediate feedback. The choices from which the student selects his answer are randomly presented with one correct symbol and either one or two distractors. The location of the correct and incorrect symbols on the screen is also randomly selected. Some examples of application would be:

a) Use of single symbol match-to-sample drills to aid in the instruction of symbol categories, component parts of symbols, and compound symbols;
b) Use of two symbol matching drills to aid in the instruction of semantics e.g. location of the tense indicator prior to the verb to teach the change in meaning of the verb; and syntax e.g. the proper orientation of the verb within a sentence, the proper position of a negation in the sentence, etc.

3. Run Blissymbol Drills
With the drills that have been created and stored on the diskette, the instructor can then run a drill and have the students work independently on the exercise. All exercises are set up on a multiple choice basis.

4. Edit the Diskette
Rather than re-create an entire symbol library or another drill, the program allows for both large and small scale changes to these two facets of the disk. This not only saves a great deal of time for the instructor but also provides for greater flexibility.

The future plans for work in this area include:

1. Continued work in refinement of the software to meet the instructional needs of as many people as possible.

2. Use of the software to conduct research on not only the utility of computers for instructional purposes, but also on the effectiveness of Blissymbolics as an Augmentative Communication System.

3. Expansion of the program to incorporate a data management system that will allow for analysis of data while using the software for data collection in the area of Augmentative Communication. In this way, the software can be utilized as a tool for research as well as for instructional purposes.

In summary, we have endeavoured to produce a software package that will meet the needs of both student and instructor. In the near future, we will also be attempting to provide a tool for assisting the researcher in obtaining data for much needed research in the area of Blissymbolics as an effective Augmentative Communication system.

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COMMUNICATION AIDS IN INTENSIVE CARE SETTINGS

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ABSTRACT - A computer-based communication system was adapted and made available to a non-verbal, brain-stem-injured, at-risk patient in a medical intensive care setting. Less sophisticated systems were provided to patients in burn and surgical intensive care.

RÉSUMÉ - Dans une unitée de soins intensif, un système de communication par ordinateur a été adapté pour une personne ayant une lesion au troncérébral. Des systèmes plus simples ont été fournis pour d'autres patients ayant subis de brûlures et suite à la chirurgie.

THE CASE OF STEPHEN BLAIR - AN EIGHTEEN YEAR-OLD BRAIN-STEM INJURED PATIENT

Goals

This young man was transferred to Hillcrest Medical Center six weeks post-injury. Prior to his admission his parents expressed intense interest in a communication and environmental control system similar to that currently used by a local C-2 quadriplegic[1] who is 12 years post-injury. In formal and informal staffings with the family, the following goals were established: (1) develop a simple nurse call system that is always accessible, and (2) develop a sophisticated system that will permit the patient to "write" messages, control electrical devices, play video games, etc.. The parents wanted these goals to be vigorously pursued.

The Rehabilitation Team

The acute care physician was a neurosurgeon; the attending physiatrist planned a rehabilitation delivery program for the intensive care setting. The patient was placed in a Medical Intensive Care Unit because he was at risk with indwelling catheters, respiratory assist, tube-feeding and with monitoring. Nevertheless, a program designed to provide a functional communication means began 3 days after the patient was admitted. Key developers of the communication and environmental control system were a rehabilitation engineer, a nurse-speech pathologist and a rehabilitation engineering technician.

Selection of Nurse Call/Control Method

This patient, even today, has no voluntary control of muscles except those associated with his head. He has good control of his eyes but squint and brow function and control are limited. He wears glasses but presence of head support causes irritation due to Rotabed action. An electromyographic switch, Prentke Romich #EMG-1, was used with fair-to-good success but long term use of surface electrodes caused irritation. Neither the Prentke Romich Brow Switch nor the NASA developed Eye-Controlled Switch were available for trial. The attending neurosurgeon suggested development of an Eye Position-Controlled Writing System which was not pursued.

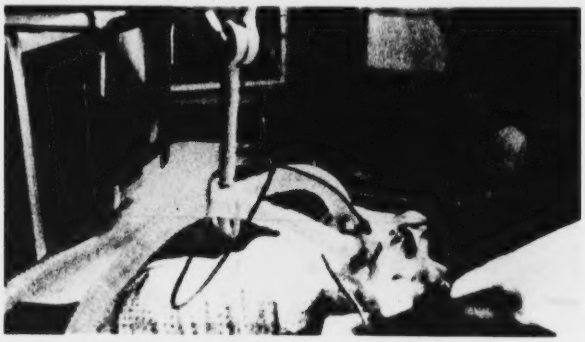

FIGURE 1. PATIENT LEARNS PUFF-SIP CONTROL

Initial trials with a puff-sip device revealed that the patient was unable to distinguish between "puff" and "sip" functions. He had double vision which, coupled with poor vision prior to injury, made the use of an E-Tran or other communication board very difficult. Nevertheless, a puff-sip training device which paired a red lamp with the "puff" function and a green lamp with the "sip" function was fabricated. Training sessions were held for one-half hour twice a day for about six weeks. At the end of this period, the patient was able to operate nurse call which was provided with acoustical feedback to inform him when nurse call had been initiated. But this was never completely functional because (1) bed* action made placement and retention of the pneumatic tube very difficult, (2) presence of the tube for long periods was uncomfortable and the patient ejected it with unpredictable and uncoordinated tongue thrusts, and (3) the patient was unable to retrieve the tube even when it was placed at the corner of his mouth.

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*Rotabed

Adaptation and Training With Apple II Computer

Medical care, feeding and personal care took precedence over communication adaptation and training. Initially it was necessary to coach the patient in every step of letter selection because of his limited field of vision and double vision. Placement of the display and pneumatic tube were difficult because the patient had to lie flat due to medical reasons.

FIGURE 2. COMMUNICATION AIDS IN INTENSIVE CARE SETTING

Installation of a Fresnel lens improved his ability to distinguish letters and to view the cursor but his limited field of view still imposed serious restrictions. A large color display was tried but the smaller green-on-green display with sharp focus proved most satisfactory. Even though his first messages were written by "remote control" (he was coached on every single move) he and his family were elated that he had "command" of this capability.

He wrote many notes to his family and friends and vented his frustrations by writing "pointed" comments to the attending staff. He played video games, the programs for which had been modified to slow the action. A menu-driven program with the Northwestern NUCDC program as the primary program was written. This enabled the patient to write text, play video games, select preprogrammed messages and to simulate operation of environmental control devices without assistance. Steve received approximately 170 30-minute training/operating sessions during his stay at Hillcrest Medical Center.

THE CASE OF ROBERT HENDERSON - PATIENT IN SURGICAL INTENSIVE CARE

This 48 year-old man was admitted to intensive care with a brain-stem injury and broken limbs. Five days post-injury, rehabilitation engineering was requested to install a suitable nurse call system and to upgrade his communication system which consisted of a message board and lipreading.

A custom-made footswitch was installed at the footboard of his Rotabed. The patient had the option of lateral or longitudinal foot motion to operate nurse call with an acoustical feedback source to assure him when nurse call was placed. This system false-alarmed when the patient was asleep and when the bed rotated. A puff-sip system proved partially effective when the patient was lucid. Placement of the pneumatic tube near his mouth was critical because head motion was restricted by rigid head support. As the patient improved, he was offered foot control, hand control and puff-sip control switch options. When it was learned that he knew Morse code, he was encouraged to communicate utilizing the beeper.

Forty-five days post injury, the patient was transferred to Tulsa Rehabilitation Center where a Cypherlog Communicator was used. This device converts Morse code signals to letters displayed on a CRT. This communication method was quite effective and the medical staff believes, accelerated the rehabilitation process considerably. The patient's voice has been partially restored and prospects of his returning to his desk job are good.

OTHER CASES

Nurse call and television control systems have been devised and provided to severely burned patients in Burn Intensive Care. This has been so successful that certain physicians will not release patients from intensive care until functional nurse call systems have been provided.

CONCLUSION

Feasibility of delivering rehabilitation engineering services to intensive care settings was demonstrated. Tulsa Rehabilitation Center contends that this is both humane and cost-effective.

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ACKNOWLEDGEMENT

Tulsa Computer Society members provide technical and material support to Tulsa Rehabilitation Center.

Interns from Oklahoma State University and Utah State Rehabilitation Services and local volunteers participated.

ÉCRIRE: SYSTÈME POUR LA COMMUNICATION NON-VERBALE FRANÇAISE EN ORTHOGRAPHE STANDARD

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RÉSUMÉ - On décrit un système français de représentation linguistique pour la communication non-verbale. Ce système, qui s'appelle ÉCRIRE, ressemble au système anglais, WRITE, en ce qu'il permet la production de tout texte en orthographe standard au moyen d'un minimum de gestes par mot. Ce nombre de gestes peut se réduire jusqu'à 1,7 par mot en sélection directe, avec l'utilisation de l'ensemble ÉCRIRE-400.

ABSTRACT - A language representation system for use in French communication devices is described. This system, ECRIRE, is similar to the English system, WRITE, in that it allows production of correctly spelled text with a minimum number of selection gestures per word, as few as 1.7 for ECRIRE-400 in direct selection mode.

INTRODUCTION

La communication sociale ainsi que la production de texte pour la communication écrite se trouvent difficiles et ralenties pour la personne qui est non-verbale à cause de déficience motrice.

La production de messages à une vitesse de moins de 3 mots par minute peut à elle-même garantir que le sujet non-verbal sera exclu de toute participation à la conversation interactive. (Goodenough-Trepagnier et al., 1984)

FACTEURS QUI DETERMINENT LA VITESSE DE COMMUNICATION

On peut considérer que le temps de communiquer un message dépend de trois facteurs: le coût (C) du système de représentation linguistique, c'est-à-dire, le nombre d'unités en moyenne par mot; la longueur (L) du code (par exemple, L=1 pour la sélection directe); et le temps (T) que met l'usager à l'exécution des gestes de sélection. Le produit de ces trois termes, C.L.T, est le temps moyen du mot (Rosen et Goodenough-Trepagnier, 1981).

Le but de l'approche appliquee dans le développement de Par lē si la b et ensuite dans celui de SPEEC, WRITE, PreSPEEC et ÉCRIRE est de trouver les inventaires d'unités pour lesquels la valeur de C soit au minimum (Goodenough-Trepagnier, et al., 1982). Des études menées avec des sujets handicappés et des sujets de motricité normale démontrent que la réduction dans C n'entraîne pas forcément le haussement de L ou de T (Rosen et Goodenough-Trepagnier, 1982; Goodenough-Trepagnier & Rosen, 1982). Le résultat en est donc que la vitesse de communication peut en effet être accélérée pour le sujet capable d'utiliser un système de ce genre.

DESCRIPTION DU SYSTEME ECRIRE

Le système ÉCRIRE comporte un choix d'inventaires d'unités (de 64 à 400). Ces unités peuvent être des mots ou bien des suites de lettres qui sont très fréquents dans le langage quotidien. La version ÉCRIRE-Espace traite l'espace comme tout autre caractère. L'alphabet au complet est toujours inclu, de sorte qu'aucun mot ne soit impossible à produire.

Dans les inventaires d'unités où l'espace fonctionne comme une 27ième lettre, les suites de lettres qui arrivent assez souvent en position finale du mot se voient déjà suivies d'espace. L'usager peut donc souvent se passer d'indiquer l'espace par un geste particulier. Par exemple, en unités du système ÉCRIRE-Espace-400, la phrase précédante se fait en sélection directe au moyen de 34 gestes (versus les 80 gestes qu'il faudrait avec l'alphabet), dont un seul est la sélection d'espace (tout seul).

La valeur de C peut être aussi bas que 1,7 pour ÉCRIRE-400, dans la conversation interactive, pour laquelle on n'a pas besoin normalement d'indiquer l'espace. Par comparaison, le C pour l'alphabet est de 4,4, soit deux fois et demi plus de gestes requis par mot. Le tableau ÉCRIRE-300 comporte, avec les unités ordinaires, des digrammes, c'est-à-dire des suites de mots qui sont elles-mêmes très fréquentes.

LA POPULATION CIBLE

Le système phonétique, Par lē si la b, est destiné aux sujets faisant la transition de communication par images ou symboles pictographiques à la communication par l'orthographe. Il s'est aussi démontré d'une certaine utilité comme support à la parole chez des dysarthriques (Guénet, 1981).

Par contre, le système ÉCRIRE se destine aux clients qui contrôlent déjà le langage écrit. En jugeant sur les expériences menées chez des usagers de WRITE, l'emploi d'un tableau ÉCRIRE en sélection directe, en ordre alphabétique, ne devrait pas présenter de problème particulier pour le client qui possède une connaissance fonctionnelle du langage écrit.

IMPLEMENTATION SUR ORDINATEUR

Nous sommes en train de développer des programmes pour produire un système qui utilisera le Commodore 64, le tableau Powerpad et le système texte-à-parole Intexte, pour permettre l'emploi des systèmes à vocabulaire illimités et au C minimal, tels que Par lē si la b, ÉCRIRE, SPEEC, WRITE et PreSPEEC, avec la capacité de production de texte et/ou de parole synthétisée. Les programmes et les précisions nécessaires pour faire fonctionner ce système seront disponibles lors de la séance d'affichage.

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Le développement de ce système a bénéficié d'une subvention de l'Association de paralysie cérébrale du Québec.

Le développement des autres systèmes mentionnés ici a été possible grâce aux agences suivantes: Ministère des affaires sociales du Québec; et le National Institute of Handicapped Research et le National Science Foundation des Etats-Unis.

DO WE KNOW HOW TO DESIGN COMMUNICATION AIDS?

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ABSTRACT - Speech Communication between the able-bodied is a very complex act, transmitting more information than that contained in the words which are used. This discussion paper examines some of the characteristics of speech communication with particular reference to the design of aids for the handicapped.

RÉSUMÉ - La communication de vive voix entre personnes normales est un acte d'une grande complexité, dans lequel on transmet plus d'informations qu'en contiennent les mots. Dans la communication que voici, on examine certaines caractéristiques de la communication verbale, dans l'optique de les appliquer principalement à la conception d'aides pour les handicapés.

How do we design Communication Aids?

What is a communication aid for?

Recent advances in technology, especially in the area of microcomputing have led to substantial improvements in the availability and the range of communication aids for the disabled - many of these have been specially designed, but a large number have been produced by "spin-off" mainly from the low-cost home computer field. There is little shortage of technology but the match between what technology provides and what is required is sometimes less than perfect. This can be because of the constraints of technology, but also because the designer has taken too narrow a view of the requirements of a communication aid. Modern technology offers a bewildering array of possibilities and thus, as we move towards more and more sophisticated aids, we need to be acutely aware of the direction in which we are heading.

In order to design a communication aid we need to know what it is to be used for. It is thus first necessary to study the communication act in detail and try to ascertain the important characteristics of it. If possible these characteristics should be preserved when an aid is used. Although little formal monitoring has been done on communication between human beings, it is clear that it is much more than just passing messages (Morris). In addition, and often subordinate to the message passing role, speech is used to communicate such important attributes as:

(a) the personality of the speaker,
(b) whether he is angry or not,
(c) his geographical, ethnic, and socio-economic background, and
(d) the relative status between the talker and listener.

If a communication aid is based on a message passing model of the communication act, the designer is tempted to neglect the above requirements.

Who is a Communication aid for?

The next question which must be asked before we can design an effective communication aid is "for whom is it intended?" Communication is an act between at least two people - thus the users of the communication aid may include:

(a) the disabled person
(b) the therapist
(c) the doctor and/or nurse
(d) the relatives, and
(e) strangers.

The importance of this list can be underlined by considering who usually makes the decision concerning which aid should be supplied - and who pays for it! It is only on rare occasions that either of these functions are performed by the disabled person. In addition, the aid may not be accepted by some of the users and may suffer rejection or even damage at their hands. An aid needs to satisfy a number of often mutually contradictory requirements, and the only solution, of course, is compromise and as much flexibility as possible. Nevertheless the designer should be aware of these conflicting requirements and try to establish some scale of values and priorities for his aid.

Modalities - paper, screen or speech?

The output from a communication aid can be printed, or appear on a computer screen, or be produced as synthetic speech. It is more important to realise, however, that these different modalities can condition meaning - thus if synthetic speech is added to a communication aid which previously used a display screen then the interpretation of the messages can well change. The characteristics of these three modalities are:

(a) paper is permanent and rather "official" as a communcation medium. It also suffers the disadvantage that it can not be easily erased (e.g. if the person being talked about enters the room unexpectedly)

(b) Screen-based output is easier to erase but still has a different impact to speech (this effect can be seen in television subtitles). Also, like printing, it is difficult to retain eye-contact when communicating by this method. Indeed, with very few exceptions, communication aids have been designed so that the relative positions of the speaker and talker are not conducive to rapport, and deny the users the body language which is so important in communication.

(c) Speech has the advantage that the listener does not have to look at the message but, as it is non-permanent, the listener has to rely on memory to decode the message, and this may be difficult with slow speech. In addition synthetic speech is very different from real speech - real speech contains very subtle distinctions, and relies on very precise timing for its effect. Speech is certainly a "natural" method of communication, but when using synthetic speech the talker and the listener may have expectations which current synthetic speech systems cannot hope to achieve. A list of some of the attributes which can be conveyed by speech have been given - few of them are present in current synthetic speech based aids.

An overriding difference in communication via most aids and normal speech communication, however, is speed, and particularly if the person has motor problems, this can lead to great frustration, and sometimes destroys the act completely. Often the speed problem can be overcome by councelling and training in the use of the aid, particularly in the use of linguistic ploys to cope with its restrictions - but this can be done much more effectively with aids that have been designed with imagination and understanding. One way for designers to gain this understanding is to try using an aid rather than simply testing that it "works".

What are the requirements for an effective aid?

It is not easy to specify the requirements of a communication aid, but it is appropriate to make some suggestions which may begin to laydown guidelines for aids of the future.

(a) Personalised - the aid should provide not only a personalisable vocabulary but also sentences and, in a speech aid, a choice of the ways to say words (Fawcus)

(b) As an advance on the above, it should be possible for the user to assume different roles; thus one might wish to say "please may I have" or "give me". A speech aid should perhaps have more than one intonation pattern, for example for the words "yes" and "no" - after all human speech can provide a very large range of meanings for these words, including indicating the reverse meaning!

(c) Expletives are an important aspect of speech for many people, but censorship can be applied to aids: for example very few fixed vocabulary aids contain such words.

(d) Normal speakers use a number of "uh-uh" type noises to inform the other person that they are listening, these should be easily available in an aid (Baker). This is particularly important as a good communication aid user will encourage the non-disabled person to do most of the talking.

(e) Fillers - in speech communcation use is made of "fillers" to slow down communcation rate; these range from the use of redundant expletives in some social groups, to the more socially acceptable "well I mean to say". As the disabled have problems with data rate, "fillers" could be used to partially overcome this problem.

Some of these suggestions have already been incorporated into some aids, but it is salutary to ponder on how far away from normal speech even the most advanced prototype aids are, and we are unlikely to be able to find a complete replacement for such an advanced communication system. Nevertheless careful consideration of the characteristics of normal speech will, I believe, pay great dividends for the designers of aids of the future.

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The author has discussed these ideas with many people but he would particularly wish to acknowledge the contribution to his understanding made by recent conversations with Eileen Kraat, Bob Fawcus and Rick Foulds.

SLOW MESSAGE PRODUCTION RATE AND RECEIVERS' IMPATIENCE

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ABSTRACT - The relationship between message rate and receivers' impatience was investigated. Subjects rated their impatience in attending to sentences presented at rates typical of nonvocal communication. The hypothesis of correlation between impatience and slow message rate was confirmed, and was particularly strong at the slowest rates.

RÉSUMÉ - L'étude examine la relation entre la vitesse de la production du message et l'impatience chez le receveur du message. 12 sujets ont évalué leur taux d'impatience en écoutant des phrases présentées à des débits typiques des nonverbaux utilisant des machines électroniques. L'hypothèse d'une corrélation entre débit lent et impatience élevée se voit confirmée, surtout pour les débits les plus ralentis.

INTRODUCTION

Methods for improving rate of communication output by disabled users of communication aids have been a preoccupation for many researchers, including the authors (e.g., Beukelman & Yorkston, 1982; Rosen & Goodenough-Trepagnier, 1982; Goodenough-Trepagnier & Rosen, 1982). One of the grounds for this concern has been that receivers are less willing to interact with device users whose messages emerge at excrutiatingly slow rates.

This study was carried out in order to determine whether the relationship between receiver tolerance and rate, and in particular the apparent intolerability of extremely slow rates, could be experimentally confirmed.

HYPOTHESES

It was predicted (hypothesis 1) that presentation rate would inversely correlate with impatience and further, that presentation rate and level of impatience would show a nonlinear relation, specifically, that there is a slow rate below which impatience is dramatically increased. It was also predicted (hypothesis 2) that decrease in attention would correlate with rate.

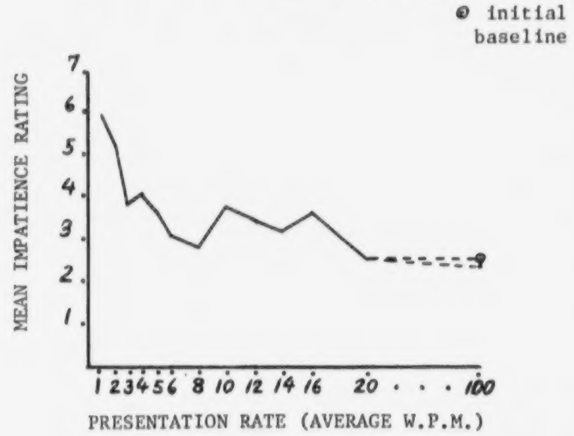
PROCEDURE AND EXPERIMENTAL DESIGN

12 Subjects between the ages of 19 and 45 participated. The task was to listen to 14 tape-recorded sentences and after each was heard, to write it down and rate his/her impatience on a scale of 1 to 7, where 1 represents a neutral reaction and 7 represents extreme impatience. The sentences were unrelated, declarative statements. Each consisted of 16 words. Although they varied in structure and semantic content, all contained numerous adjectives and content nouns. Each Subject heard each of 12 of the sentences at one of the following average rates: 1, 2, 3, 4, 5, 6, 8, 10, 12, 14, 16, and 20 w.p.m., and the two other sentences at 100 w.p.m. Words were presented at randomly varied intervals that averaged out to those rates.

Presentation trials were constructed to form a balanced block design. Each sentence and rate were tested equally often and appeared equally often in each presentation position, with the exception that the 100 w.p.m. trials always appeared in initial and final positiion. All other rates were paired with all sentences equally often. Solitaire was used as a 'distractor' task. Subjects could start a new game at any time during a sentence presentation.

RESULTS

FIGURE 1: MEAN IMPATIENCE RATING AT EACH PRESENTATION RATE



Hypothesis 1

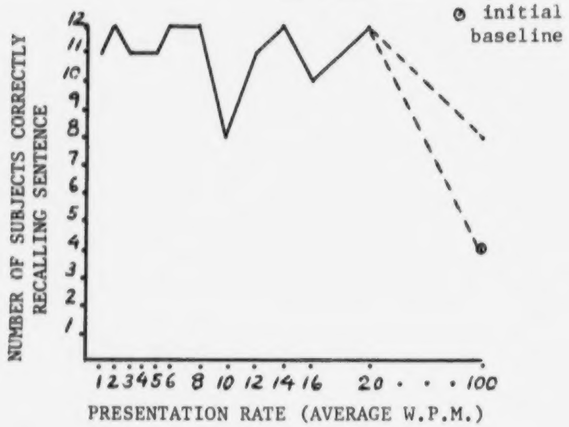
Visual inspection of Figure 1 reveals a strong linear relationship between impatience rating and rate, for rates up to 8 w.p.m. Analysis of these data gives a correlation of -0.93.

The difference in mean impatience ratings between rates of 1 and 2 w.p.m. and rates of 3 and 4 w.p.m. is highly significant (p= .0006). In contrast, the mean impatience for rates 3 and 4 does not differ significantly from the mean impatience at rates 5 and 6 w.p.m. (p = 0.2328).

Hypothesis 2

Sentences were scored as incorrect if they were substantially different from the target. Figure 2 shows the number of Subjects who correctly recalled the sentence they heard at each rate. It can be seen that attention, as measured by sentence recall, does not correlate with rate. At most there appears to be an inverse relationship between rate and recall. This may have been due in part to Subjects' unpreparedness at the time of the initial sentence and in part to the lack of time for rehearsal when sentences were presented at 'normal' (100 w.p.m.) rate.

FIGURE 2: SUBJECTS' RECALL OF SENTENCE AT EACH RATE



DISCUSSION

It is significant that the impatience versus rate data are very strongly inversely correlated for rates of 8 w.p.m. and lower. This is consistant with our expectation that impatience is particularly sensitive to very slow rates. The particularly severe intolerability of rates lower than 3 w.p.m. was also consistent with Subjects' reports and behavior (e.g., groans) when sentences were played at average rates of 1 and 2 w.p.m.

The sentence recall and impatience rating task is in many ways not a fully appropriate model of communicative interaction between a device user and a receiver. In particular, listeners are rarely concerned with memorizing the sentence they hear but rather with extracting the content. That this was a memory task probably accounts for the high level of attention Subjects maintained and their generally high scores on sentence recall.

Slow presentation rates allowed Subjects time to rehearse and thus to recall their sentences correctly. Subjects reported that this acted to reduce their frustration and thus their impatience, since they wanted to obtain good memory scores. It is remarkable that despite this positive effect of slow rate, the relationship between slow rates and impatience, and the particular intolerability of listening to sentences at rates of 1 and 2 w.p.m., is evident. The hypothesis of a minimum tolerable range of rates for interactive conversation appears to be confirmed.

CONCLUSION

Any improvement in output rate is beneficial to the nonvocal device user. On the basis of these results however it appears that rate improvements which allow the user to produce messages at the rate of at least 3 w.p.m. are essential, if conversational interaction is the goal. Messages produced at rates slower than 3 w.p.m. will probably be attended to only on playback.

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AN ADAPTIVE AND PREDICTIVE COMMUNICATON AID FOR THE DISABLED EXPLOITS THE REDUNDANCY IN NATURAL LANGUAGE

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ABSTRACT - A communication aid for the disabled adapts to the vocabulary of its user and offers optimised predictions. Using a disabled persons interface, a user exploits these predictions to improve the efficiency of communication.

RÉSUMÉ - Un appareil d'assistance pour la communication des handicapés s'adapte au vocabulaire de l'utilisateur et offre une prédiction optimisée. En utilisant une interface pour personnes handicapées, l'utilisateur peut exploiter ces prédictions pour améliorer l'efficacité de la communication.

INTRODUCTION

Microcomputer technology has made possible the development of a variety of economical and portable communication aids to suit a wide range of disabilities. These developments have increased awareness of the problem of low communication rate which restricts communication and environmental control for many disabled persons. In cases where there is motor impairment but little or no mental dysfunction, communication rate is largely determined by factors such as speed of motor response and physical fatigue. There is a need to optimise the efficiency with which a disabled person can enter information into a communication aid, and thus reduce the time and physical effort of communication. This need inspired the development of predicitive communication aids which anticipate users' intentions.

PREDICTIVE AND ADAPTIVE AIDS

A predictive facility is one which suggests, on the basis of preceding input data, what the user wants to do next. The user can select or reject the suggestion. If it is selected, a net benefit accrues because only one user action was required to select an item which would otherwise have needed several actions. In the case of typing text, there are predictive systems which predict bigrams or trigrams, or complete words, to the user. The predictions are conventionally derived from fixed knowledge bases, stored n-gram and word lists which represent known statistics of language use. These knowledge bases are, however, inflexible, and do not evolve with the vocabulary of the user. They are also usually derived from written material rather than spoken, and may not adequately represent the vocabulary required by the user during other activities like work or conversation. More recently adaptive functions have been incorporated to enable such devices to self-optimise to the vocabulary of the individual user (4,5). Adaptive systems have variable knowledge bases which lead to further improvement in communication efficiency.

A predictive system essentially improves communication efficiency by exploiting redundancy in the information which it processes. Natural language is inherently very redundant, hence the efficiency of a typing or writing aid can be significantly improved by incorporating prediction. This paper describes an adaptive, predictive communication aid which has been developed from the principles of abstraction of linguistic redundancy investigated in earlier work by one of the research group (1,2,3).

The system is modular, with an adaptive predictor in one module, and a disabled user's interface in another.

INTERFACE FOR THE DISABLED

The interface module presents to the user a single display screen divided into three separate areas - a scanned-matrix area, a prediction list area, and a text area. The user interacts with the system via a disabled persons switch (e.g. suck-blow switch). The matrix area contains alphanumeric, punctuation and control characters. The user initiates matrix scan and selects a character from it. The prediction list area then fills with the most portable items (words or phrases) in the user's common vocabulary which begin with that character. With one switch action the user can move to scan the prediction list, from which an item may be selected with one further action. The item is then added to the text displayed in the text area of the screen. Should the desired item not lie in the prediction list, the user selects the second character of the required word or phrase from the character matrix. Prediction rejection is implicit in the act of choosing another character, no extra control action is required. When the second letter has been selected, a new prediction list is presented based on the first two characters of the item. This cycle repeats until the user either enters a complete word terminated with a space, or selects a prediction. The earlier in this process a prediction can be selected, the greater is the saving to the user.

The prediction list is limited in length to ten items as a compromise between typing efficiency and the cognitive effort of item selection. These items are the ten most probable in the user's current vocabulary which begin with the selected character(s). They are ordered alphabetically on the display, and presented as complete words rather than word fragments, in order to further assist recognition. Before the first character of any word is selected, the prediction area contains a list of the ten most common words in the user's vocabulary. It is thus possible for the user to select one of these words without entering the character matrix. All predictions can, however, be ignored by the user, who can use the system as a simple text typing system. This latter facility may assist novice users while they familiarise with the system. Errors made during text entry can be corrected by selecting the deletion function from the matrix. The prediction list is updated during deletion so that another item may be selected immediately upon deletion of the error.

ADAPTIVE PREDICTION MODULE

The predictions are made by the adaptive predictor module, which contains a dictionary representing the current vocabulary of the user. An advantage of this system is that it can maintain and automatically optimise special purpose dictionaries for specific contexts, so the user can select an appropriate dictionary to suit the subject matter and improve prediction efficiency. A dictionary is automatically acquired by the system during normal "typing" on the basis of redundancy abstraction discussed elsewhere (1,2,3). When the user has completed a word, it is inserted into the dictionary unless it is already present. If it is present, its usage record is updated instead. The word probability ranking within the dictionary is derived from the usage records, hence use of the word increases the probability of its appearance in the prediction list. This immediate dictionary update enables the system to adapt quickly to changes in context.

The dictionary can acquire new material by two methods; (a) on-line, from the user's input, as above, and (b) off-line, from a disc file of stored text. Hence a dictionary may be created quickly if a proposed user already has text files in computer-compatible form. Alternatively, the user can choose to start with a non-optimised dictionary of standard words, or with no dictionary at all. In either of these latter cases, the system will gradually adapt to the user's own vocabulary. (In order to reduce prediction response time to an acceptable minimum, the complete dictionary is accommodated and searched within main system memory, which currently limits dictionary size to the order of 1000 words, or approximately 75% of common vocabulary (6). When this maximum size is reached, the words of lowest probability are removed to make way for new acquisitions.) The dictionary, which resides on disc between periods of use, thus evolves over a long period of time and adapts to the changing vocabulary of the user. If required, a user can maintain several context-oriented dictionaries, each one optimised for different tasks or activities which the user pursues, and change rapidly from one to another.

CONCLUSION

A microcomputer based typing aid for the disabled has been developed. The system, which is both adaptive and predictive, exploits linguistic redundancy in order to reduce the time and effort involved in typing text. It can personalise the data on which predictions are made; this and the facility for context change under user control ensures that user's switching effort is minimised.

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CLINICIANS' PAIRED COMPARISON JUDGMENTS OF COGNITIVE DEMANDS IMPOSED BY NONVOCAL COMMUNICATION DEVICES

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ABSTRACT - A study was carried out to determine experienced nonvocal communication clinicians' ratings of the relative demands of communication aids for selected linguistic and cognitive abilities. Paired comparison judgments were made by 6 clinicians about 9 systems in respect to 9 abilities. Implications for devising an explicit prescription guide are discussed.

RÉSUMÉ - La communication présente les résultats d'une étude menée auprès de 6 cliniciens, experts dans la prescription des techniques pour faciliter la communication chez les nonverbaux. La tâche était de comparer 9 techniques, en les prenant deux à la fois, pour juger laquelle des deux requiert plus chez l'usager de certaines capacités cognitives (par ex., la mémoire). Le rapport en expose les implications pour le développement d'une approche systématique à la prescription.

INTRODUCTION

Development of a procedure for the prescription of nonvocal communication aids entails, among other things, identification of the linguistic and cognitive abilities needed for the operation of various devices. Accordingly, a list of candidate abilities was drawn up and submitted individually to six clinicians with extensive experience in prescribing augmentative systems and techniques. The abilities were 1) spelling recognition, 2) spelling production, 3) reading comprehension, 4) general intelligence, 5) vigilance and attention, 6) planning and programming, 7) memory for sequence, 8) memory for location and 9) general memory (Goodenough-Trepagnier & Rosen, January 1983). The experts were asked to evaluate 9 nonvocal communication systems in respect to their relative demand for these abilities. The systems were specified variants of the following: A) letter-board, B) WRITE-300, C) TIC, D) Autocom, E) ETRAN, F) Handivoice 110, G) Handivoice 120, H) Morse code system, (Wilson, 1981) and I) Canon.

METHODOLOGY

This evaluation was carried out by means of the paired comparison technique, which involves the respondent answering questions of the type: which of two devices (A or B) has the greater demand for each ability (e.g., spelling production). In all, each clinician made 324 (36 device pairs x 9 abilities) paired comparisons. Techniques such as paired comparisons make use of people's ability to make binary judgments without asking them to answer the much more difficult question of *why* they made those particular judgments. Analysis produces lists which rank order devices according to their perceived demand for each ability. The paired comparison data may be checked for consistency. The data is consistent to the extent that intransitive situations such as the following are *not* present: Device A requires more of Ability 1 than Device B, Device B requires more of it than C, and C requires more of it than A.

RESULTS

Table 1, below, presents the Spearman correlation coefficient for overall rankings of each ability by all 6 judges. This analysis shows several interesting results. Spelling Recognition and Reading Comprehension are very highly correlated (.98). This suggests that judges may have the same device features in mind when making device comparisons in respect to these two abilities. Also, General Memory correlates quite highly with General Intelligence (.92) and Sequence Memory (.90) while the latter are fairly well correlated (.82).

Table 1
Spearman Correlation Coefficient for Overall Rankings of Each Ability by All 6 Judges

	2) SP	3) RC	4) GI	5) VA	6) PP	7) SM	8) LM	9) GM
SR	-.52	.98**	.57	.25	.35	.20	.48	.45
SP		-.62	-.77**	-.40	-.62*	-.68*	-.85**	-.88**
RC			.68*	.37	.48	.33	.55	.58
GI				.70*	.92**	.82**	.62*	.92**
VA					.85**	.83**	.18	.68*
PP						.90**	.50	.87**
SM							.52	.90**
LM								.67*

* $p \leq .05$
** $p \leq .05$

Spelling Production is fairly strongly *negatively* correlated with each of the other 8 abilities and is the *only* one *negatively* correlated with any other. This strongly suggests that Spelling Production is viewed by the judges as related to the other ability demands but in some reverse manner. That is, if a device tends to place a high demand on spelling production, it will tend to place a low demand on the other abilities.

The smallest correlation values are also of interest since these would suggest orthogonality or independence of the contrasted abilities. For example, device rank under Vigilance/Attention is essentially uncorrelated with that under Location Memory, indicating that these two ability demands are perceived as arising from quite different device features. The same may be said for Spelling Comprehension versus Sequence Memory and possibly for Vigilance/Attention versus Spelling Comprehension.

Inter-judge disagreement was considerable with respect to rank ordering of devices according to their demand for these nine linguistic and cognitive abilities. However when each individual's rank orderings were compared to the orders derived from the group on average, there were significant correlations ($p < .05$) in the majority of cases, as well as absence of negative correlation values or strong rank order reversals. As can be seen in Table 2, which presents the Kendall coefficient of concordance for the 6 judges' rank ordering of 9 devices, the most general agreement was obtained for General and Location Memory, somewhat less for Planning, Vigilance, Sequence Memory and General Intelligence, and least for Spelling Production and Recognition and Reading Comprehension.

Table 2
Kendall Coefficient of Concordance (W)
for 6 Judges Rank Ordering 9 Devices

1) Spelling recognition	.346
2) Spelling production	.525
3) Reading comprehension	.431
4) General intelligence	.594
5) Vigilance and attention	.617
6) Planning & programming	.616
7) Memory for sequence	.606
8) Memory for location	.650
9) General memory	.721

W=0 no agreement
W=1 perfect agreement

Further results and analysis may be found in Goodenough-Trepagnier & Rosen, April, 1983.

DISCUSSION

High levels of clinician agreement in ranking suggests that the abilities for which this agreement is obtained should be considered important ones to retain for the development of the prescription procedure, since the implication is that levels of this ability will affect success differentially on various devices. At least that should be the case if we make the interpretation that high agreement among expert clinicians means this ranking is probably correct. However how important a role each ability is expected to play in device operation is not derivable from these data.

At the same time, abilities for which there is not general agreement as to how devices rank in respect to them should not be excluded from further study. All the listed abilities are ones which have been judged relevant in the abstract by these clinicans, according to their written comments. Further, it is evident, a priori, that an ability such as spelling production is required for device use since the 9 devices rated all employ the alphabet. Clinicans are simply not in agreement about how various parameters of devices dictate a need for certain abilities.

Each practictioner who served as a respondent in this study is experienced and successful in the prescription and management of nonvocal communication techniques. However, extracting from their judgments of devices' relative demand for cognitive abilities, information which can contribute to the development of an explicit prescription procedure, to be used by less expert practictioners, is quite problematic. An experimental approach to the identification of abilities involved in nonvocal communication device use, and to the calibration of the demand for these abilities in terms of device parameters, is required. A study based on this need has been planned and pilot data collected. This study, which will result in calibration formulae relating the dependence of performance on each relevant ability to the values of the important parameters of each device, will also provide an experimental test of the clinicians' perceptions.

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A HIGH-EFFICIENCY FLEXIBLE KEYBOARD INPUT ACCELERATION TECHNIQUE: SPEEDKEY

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ABSTRACT - A general-purpose string substitution algorithm has been developed which can increase the input rate to 200-300% of the standard input rate on a standard 60-key keyboard, with higher rates for keyboards with a larger number of keys. The algorithm is flexible enough that it can also implement any abbreviation expansion technique, as well as many level and encoding techniques, as subsets of itself.

RÉSUMÉ - Un algorithme universel de substitution de chaînes a été élaboré avec les résultats suivants: la vitesse d'introduction avec un clavier standard de 60 touches est plus rapide de 200 à 300 %, et elle est encore plus rapide pour les claviers comptant plus de 60 touches. La souplesse de cet algorithme est telle qu'il est possible de mettre en oeuvre toute technique d'extension d'abréviations et des techniques de codage au niveau que l'on veut; ces techniques constituent des sous-ensembles de l'algorithme.

INTRODUCTION

Standard English spelling, in an attempt to be semi-phonetic, uses many more letters to "spell" words than is necessary to make them unique from each other. A person's "typing" speed could thus be increased if the unnecessary letters were simply omitted, or the words were spelled in shorter but still unique fashions. Unfortunately, this would make it difficult for individuals not familiar with the contracted form to read the text. With modern computers, however, it is a simple matter to "teach" the computer what the abbreviations and expansions are, and to have the computer automatically translate the contracted forms into full-length words as they are entered. It would not be necessary or even appropriate to contract all words that might be used. Very commonly used words, however, and words which are long or difficult to type, would be prime candidates for contraction.

Such a speed-typing technique could be of great benefit to handicapped individuals. With the particular algorithm described here, it is possible to increase the speed to between 200% and 300% of the normal typing rate when using a standard keyboard (approximately 60 keys). For aids or keyboards which have a larger number of keys, even greater gains are possible.

PAST WORK IN THE AREA

Because of the advantages and straightforward nature of abbreviation expansion, a number of approaches have been proposed in the past. In one scenario, abbreviations were all terminated with some type of special terminator character. For example, the "." could be used, or a special "EXPAND" key could be used. With this technique, the individual would type out the abbreviation and then hit the expansion key. This approach yielded 26 two-keystroke abbreviations (a single letter plus the expand key), 676 three-keystroke abbreviations (two letters and the expand key), and 17,576 four-keystroke abbreviations. It should be noted, however, that many of these abbreviations would not be particularly readable, since they would result in such unlikely abbreviations as "QXX expand" or "QQP expand". A second approach used the numerals to provide a self-terminating ten-branch abbreviation expansion technique (Kelso & Vanderheiden, 1982). With this technique, codes were comprised of zero or more letters, ending with a numeral. Thus, the codes would look like "1", or "A1", or "BJ5". Whenever the number was encountered, the system would immediately know that an abbreviation was being typed in, look it up, and replace the abbreviation with the expansion. To type regular numbers, the abbreviations feature would simply be turned off. With this approach, the number of short codes was significantly increased. There were 10 one-keystroke abbreviations, 260 two-keystroke abbreviations, 6,760 three-keystroke abbreviations, and better than 175,000 four-keystroke abbreviations. Once again, number of nonsense abbreviations would still appear. The number of nonsense abbreviations in the short keycodes, however, would be smaller.

THE UNUSED INITIAL N-GRAM EXPANSION TECHNIQUE
(SPD-KEY Translation Technique)

The proposed expansion algorithm is believed to be the most efficient possible abbreviation expansion routine. One reason for this is that all of the other abbreviation expansion routines are subsets of it. In addition, it provides greater flexibility and the greatest number of short codes.

With this approach, anything can be used as an abbreviation, as long as it is not itself a word or the initial letters of a word which the individual will want to be using. For example, the following are all legal abbreviations: "BT", "B4", "BTW", "ABV", "R2D2", "BR ", "G.V." and "GV".

In the above examples, you will note that none of the letter pairs or letter sequences are the legal beginnings for any word. The letters "BR" would be a legal word beginning, and therefore should not be used as an abbreviation. In the above list, however, you will note that the abbreviation was B-R-space. Since no words begin with a B, followed by an R, followed by a space, this would be a legal abbreviation. Please note in this case, however, that this is a three-letter abbreviation, not a two-letter abbreviation, since hitting the space bar constitutes a keystroke. Similarly, hitting a "." or a special character would also be a third key. Other codes, such as "BRT" and "BRK", could also be used at the same time as "BR ", and would be just as efficient.

A special "rebreviate" key is also provided, greatly enhancing the function, power and speed of SPEEDKEY. The rebreviate key causes any expansion to instantly be transformed back to its contracted form. With the rebreviate key, it becomes possible to use character sequences which may show up as the beginnings of (rarely-used) words. For example, "PN" could be used as an abbreviation for "PHONE" without requiring a trailing space. This would give a very convenient 2-key abbreviation, but would still not outlaw the use of "PN" to spell "PNEUMONIA", in the rare cases where it comes up. The individual would simply type "PN", and the word "PHONE" would show up; hitting the rebreviate key would return it to "PN", and the user would continue to spell out "EUMONIA". The rebreviate key can also be used immediately before typing an abbreviation, and the algorithm will automatically skip over the next occuring expansion. For example, the individual could have hit the rebreviate key first, and then typed "P-N-E-U-M-O-N-I-A". When the "PN" was encountered, no expansion would be made. Striking the rebreviate key twice in succession automatically turns off the abbreviation expansion function until the key is struck a third time. Thus, the abbreviation expansion routine can be totally disabled, easily, at any time.

One very powerful consequence of the rebreviate key is that the numbers (and other special symbols) on the keyboard can also be used for words such as "the", "you", "to", "and", "will", "that", "is", "have", "what", etc., so that these frequently used words can be activated with one keystroke. This is important, since more than 20% of all of the words spoken and 15% of the keystrokes can be accounted for by the most 10 most frequently used words in a person's vocabulary. The numbers (and other symbols) can still be used in their traditional form when required by simply hitting the rebreviate key before the first number in a series, or hitting the rebreviate key twice to disable Speedkey when extended or frequent numbers are going to be used. In general, however, the numbers are used a very, very small portion of the time compared to the 10 most frequently used words. As with all aspects of Speedkey, however, an individual may choose to utilize the number keys for abbreviations, or may choose not to use them, entirely at his or her discretion.

Another major feature of Speedkey is the "prefix" key. With this key, any letter or letters can be automatically to the front of whatever is being typed, before it is looked up in the memory of the unit. For example, if an * key is pushed, and then the prefix key, all abbreviations will be looked up with an * appended to the front. This technique can be used to easily "change" the expansions for all of the abbreviations when special occasions arise. For instance, there may be some applications or situations where an individual need only respond using one of 10 or 20 responses. The individual could then key these into memory as two-character abbreviations consisting of an asterisk plus any single letter or number. Later, whenever he needed to access these, he would simply hit "*", then the "PREFIX LOCK" key. Thereafter, each time he struck a number or letter key (a single keystroke), the desired response would come forth. Hitting the PREFIX key again would turn off the function. In this fashion, special vocabularies as well as "levels" can be implemented with Speedkey. If desired, certain abbreviation/ expansion pairs can also be designated as "universal"; thus, they will always work in their standard fashion, even if a prefix is invoked. In this case, the computer will first check the list with the prefix added, and, if it finds no item, will then look for universal words without the prefix.

Comparing this technique to the previous approaches: with Speedkey on a standard 60-key keyboard, one would have the potential for 10 to 14 1-keystroke abbreviations, 950 2-keystroke abbreviations, and 4,500 3-keystroke abbreviations, etc.

EXAMPLE

Text:

Dear sirs,

I was very happy to hear from you on your plan to develop a communication aid for handicapped individuals.

Speedkey strokes: (slashes added here for clarity)

ds/1/w5/vy/hy/2/hr/fm/3/o /yr/pln/2/dv/9/cm/
a2/4/hc/idv/BACKSPACE.

Abbreviations are always interpreted as beginning following a space. The space may be typed in from the keyboard, or come from the previous expansion. The efficiency of the system is entirely dependent upon how much the individual wants to utilize the features. A gain of about 200% of normal typing can be achieved by using short abbreviations for only the first 100 most frequently used words. This gain can be increased to around 300% of normal for general text, and higher for text utilizing words or phrases common to the individual. In the above example, slashes are used to indicate points where automatic expansion would take place.

Noting that the salutation includes the comma, carriage returns, and indent, and that the other abbreviations include the trailing spaces, this is a reduction from 123 keystrokes to 38 keystrokes, or an increase of approximately 310% of normal rate. The text on the screen, of course, would only appear in its fully expanded form; thus, message receivers and the users themselves would be looking at the output as if it had been typed out.

Full implementations of the Speedkey technique are currently underway by the Trace Center and other research groups. Programs which utilize Speedkey should be available within six months for at least the Apple, the Epson HX-20, and the IBM PC computers.

SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 15

TECHNOLOGY DIFFUSION AND PRODUCT DEVELOPMENT/
DIFFUSION DE LA TECHNOLOGIE ET MISE AU POINT DES PRODUITS

TECHNOLOGY TRANSFER: SOME CONVENTIONAL AND UNCONVENTIONAL SOLUTIONS

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ABSTRACT - Transfer of technology for the handicapped is treated in terms of practical problems and solutions, with examples from the experience of the Smith-Kettlewell Rehabilitation Engineering Center in the field of aids for the blind. Experience both with the usual commercialization process and with several experimental approaches is described.

RÉSUMÉ - Le transfert de technologie pour les handicapés est traité en termes de problèmes et de solutions pratiques, en utilisant des exemples tirés de l'expérience du Smith-Kettlewell Rehabilitation Engineering Center dans le domaine des aides pour les aveugles. On décrit des expériences avec les méthodes de commercialisation habituelles et avec diverses approches expérimentales.

I. INTRODUCTION: THE PROBLEM

The problem of transferring rehabilitation technology from the laboratory to the user is perhaps the most pressing one facing the field of rehabilitation engineering today. Various theories on this subject have been the topic of many (usually fruitless) discussion groups in conference sessions. The basic problems can be stated as follows.

(a) Market Size, Definition, and Ability to Pay

This is the greatest single problem, especially for the more specialized devices where, although the prospective user's need is extremely severe, the total number of these users may be only tens or hundreds, and their ability to pay for expensive hardware is usually limited. Commonly, in academic discussions of the technology transfer problem, this difficulty is theorized away by stating that devices should be designed to appeal to a much broader market than just the handicapped group whose problem it is designed to solve. We are admonished to aim for devices which are as useful for the non-handicapped as for the handicapped. This worthy goal is, however, not always attainable. Particularly in the vocational field, specialized equipment is needed to match a specific combination of handicaps to a specific vocational task. The number of blind machinists, for example, may always be limited, and the special adaptive equipment they require is of little value to anyone else.

(b) Preproduction Engineering

The process of converting a laboratory prototype into a producible item, and paying for the tooling required for production is a major obstacle to manufacturers when markets are small, nebulous, and not affluent.

(c) Inexperience of Researchers

Research grants are based on a mandate to do research only, and most researchers are not at home in dealing with representatives of private industry. Many also have unrealistic ideas regarding the production and marketing costs for their inventions.

(d) Other Difficulties

The mass of regulations which must be satisfied before certain devices can be brought to the market effectively prevents some devices from being commercialized, and adds to the cost of others. The complexity of the third party payment mechanisms is also a formidable obstacle.

Other difficulties abound, but the purpose of the present paper is to deal with solutions rather than problems. Some of the ways in which the above problems may be overcome in practice are outlined below.

II. CONVENTIONAL SOLUTIONS: SOME VARIATIONS

The rehabilitation engineering system in the United States is based largely on the assumption that private businesses and entrepreneurs will step in to produce needed technology for the handicapped. In many cases, this assumption is justified. In others, it is absurd.

We have tried several variations on the theme of commercial distribution of aids. These can be divided into the following categories, with practical examples given for each.

(a) Use of Sheltered Workshops for Manufacture

The Smith-Kettlewell Light Probe was originally manufactured by the San Francisco Lighthouse for the Blind. Our staff cooperated with the Lighthouse staff to devise suitable jigs and fixtures to enable manufacture by blind and partially sighted individuals.

(b) Collaboration with Major Companies in Product Development

The Rehabilitation Engineering Center collaborated with Telesensory Systems, Inc. in the development of volatile braille displays, which were later incorporated into TSI's Versa-Braille product.

(c) Small Companies

Naturally, large companies are not attracted or adapted to the production of short runs of specialized devices, and it is often the very small business which shows interest in such aids.

Several of our (often sensory aids are now being manufactured by small family-owned) companies. The Rehabilitation Engineering Center usually cooperates fully in delivering a "production-ready" package to this type of manufacturer, who cannot afford large expenditures for "tooling up." Sensory aids developed by our REC currently or soon to be falling into this category include our Receptionist Mat, Auditory VU Meter, Light Probe, Piano Tuning Aid, Talking Signs, Meter Reader Kit, Dynamic Meter Reader, and the Holmlund-Alden Vibrotactor. The principal problem with this type of research utilization is the need for a suitable distribution outlet. This problem is discussed below.

(d) Spin-Off Operations

Occasionally, an outside manufacturer can be interested in the technology used in certain aids for the handicapped, even though the manufacturer has a broader market in mind. This was the case with our Talking Signs technology, which has been adapted by Kinematics Research, Inc., an elevator controls manufacturer, for use in talking elevator modules.

(e) Distribution Methods

The distribution of aids produced by small companies can often be carried out through existing retailers such as the mail order operations which distribute aids to the handicapped. We have so far utilized this arrangement in the case of the Receptionist Mat and the Light Probe. We are also obtaining cooperation from a major correspondence school in the distribution of our Kits (see below). If this type of arrangement is not possible (for example, if expected sales volume is not sufficient to meet the criteria of the distributor), then reliance must be placed on word-of-mouth, manufacturer-sponsored advertising, data banks such as ABLEDATA, etc., for making consumers aware of the availability of the product. This situation is less than ideal.

III. UNCONVENTIONAL SOLUTIONS

The following methods of research utilization, which bypass or augment the normal manufacturing and marketing process, have been tested experimentally by our REC. We have found these methods to be particularly suitable for those specialized devices for which the user population represents only a fraction of the total blind community.

(a) Distribution of Circuit Diagrams

We have followed the practice of maintaining a file of all circuit diagrams and other information pertaining to each vocational sensory aid we have developed. We receive frequent requests from rehabilitation counselors, blind consumers, and various agencies and individuals for our plans for particular sensory aids. Since most of the devices employ relatively simple circuitry and means of fabrication, the requesting individual can have the device in question built by a local tradesman.

(b) Handicapped-Oriented Technical Magazine

We have instituted a quarterly technical magazine for the blind and visually impaired-the Smith-Kettlewell Technical File. The publication, available quarterly in braille, large print, and cassette forms, serves many purposes. One of the basic goals is to allow interested blind persons to build their own sensory aids. Under the editorship of William Gerrey, the Technical File has published a complete soldering course for blind individuals, full instructions for the fabrication of many of the sensory aids developed at our Center, and articles on electronic theory and practice. The international subscribership of between 300 and 400 was recently polled by Lesley Brabyn in a survey to determine reader satisfaction with the magazine and the degree of practical impact it was having. Among the 35 percent of subscribers who responded to the survey, a total of 107 sensory aids have been built by or for the readers (in a two-year period), using the plans and instructions contained in the Technical File. In general, the respondents were most enthusiastic about the impact the magazine was having on their lives.

(c) Printed Circuit Board Kits

We have begun experimentation with the use of circuit board kits with specially developed braille and raised-drawing instructions for low-cost distribution of certain sensory aids. The special instructional format makes it possible for a blind individual to assemble the kit without assistance - although print instructions are also included to allow assembly by sighted individuals.

Our first experimental kit is a Meter Reader with an audio-braille output. To date, approximately six of these have been successfully assembled by blind individuals within and outside our laboratories. We have identified a small manufacturer willing to produce the kits, and we are obtaining the cooperation of a correspondence school for the blind in their dissemination. It is hoped that this use of kits will allow certain sensory aids to be made available at lower cost than would otherwise be the case. The kits also have considerable educational value.

(d) Catalogue of REC-Developed Aids

We have published, in print and braille, a catalogue of most of the vocational (and some other) aids developed at the Smith-Kettlewell REC. This *Catalogue of Vocational and Educational Aids*, edited by Lesley Brabyn, contains photographs, descriptions, and details of availability and cost for all of these aids. In cases where the aid is not available commercially, the cost of parts and the source where free plans and circuit diagrams can be obtained are listed. The catalogue has been distributed widely to rehabilitation agencies and professionals, as well as blind consumers. It is also circulated to potential manufacturers, who are encouraged to consider production of those aids not already commercially available. Response to the catalogue has been enthusiastic, and we receive many requests for it. The number of agency and consumer inquiries resulting from this type of publication can also provide an indication of user demand for particular aids. This information can be useful in interesting potential manufacturers.

(e) Technical Training Program

Further indirect assistance to our unconventional research utilization efforts is provided by our informal Blind Technicians Training Program, operated under private funding. The program allows blind individuals to obtain practical experience in electronic design and fabrication, at the same time facilitating the development of training materials which will ultimately be utilized by educational institutions with blind students. Apart from its other benefits, the program provides a pool of blind subjects who provide input and feedback to our research and development program. For example, the development of the printed circuit board kits (see above) was greatly facilitated by the feedback provided by trainees.

IV. CONCLUSION

The practical solutions and examples outlined here by no means represent a panacea. Given the non-ideal world in which we operate, we are likely to improvise non-ideal solutions. It is hoped, however, that some of the above experiences will aid other rehabilitation engineers in the constant struggle to get laboratory prototypes off the shelf and into the hands of users.

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THE TECHNOLOGY PUSH-DEMAND FULL SITUATION - MANUFACTURERS-USERS GAP IN ASSIST DEVICES FOR HANDICAPPED: A TENTATIVE APPROACH TO ITS RESOLUTION

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ABSTRACT - During the last few years, many assist devices, especially communication devices, have been developed and commercialized for handicapped persons. Some institutions are not interested in these devices, while many others have devices which they do not use. Our purpose is to grasp the reason why new technologies meet so much resistance: lack of information on the users' side; inadaptation of the devices or of their implementation; lack of psychological knowledge as to what should the function of the device be.

Introduction

Working as a research psychologist in a University and in institutions for C.P. children, we are deeply involved in the problem of assist devices (motor aids or communication aids) and their use in institutions.

The first contact with people in institutions using devices generally turns out to be enthousiastic for one of the following reasons :

a) You are coming when a new device is just being received;

b) you talk with the only person who is using the device in the institution;

c) "they" want to show you that they are a modern institution aware of developmental and technological problems;

d) the child presented to you, because he uses the device, is the only one in the institution who does something with it;

Having a further look and when a deeper discussion is engaged, we find out that :

a) Enthousiasm for a new device does not necessarily implies knowledge of it, of how it works and what can be done with it according to the different cases;

b) the person in charge of the device might also be justifying his position by relying on the mere existence of the device(s) rather than by the educational program performed with it;

c) after some embarassing questions, it appears that devices are not used daily as this would break up the daily routine and change habits;

d) you are shown the miracle occured with a severe C.P. child who will write for you a beautiful letter on his micro-computer, but nobody can explain how he came to learn to do this.

After such observations on the battle field, we came to think of manufacturers and institutions. The devices are produced by small companies, some of them still convinced that the product they offer will bring about a much better situation than the ones existing previously. This is true for simple devices such as pointing sets. They are still arguing as some years ago : "my machine is the most powerful", which makes it a good reason to buy it, even if you do not have in the institution any therapist able to type a single instruction for the machine or if it will take you months or years to do what you wanted with it (supposing that by chance the institution has a program).

Institutions expect from devices and from their dealer what a small child is expecting from his father who know everything and therefore will solve all the problems. As a magic solution does not come after several trials, they go from a blind faith to doubt, criticism and distrust.

Institutions generally expect that small companies sell them devices at low prices, and this price should further include the training of staff, all implementation problems and also the company should act as a long term educational adviser. No wonder that manufacturers do not fulfil such comitments. Few non profit organizations fulfil them. In contrast with their many demands, institutions are often not able to give any feedback whatsoever as to their own attempts.

This leads institutions to some bitterness as they feel manufacturers should not only sell devices, but also the relevant developmental charts and application programs.

Research, development and psychology

Research and development people generally function outside institutions and many educational psychologists are convinced that they develop new tools for their own satisfaction. Besides, they think they generalize what cannot be generalized and that they do not take into consideration basic psychology and pedagogy.

After a classical european formation, a psychologist has no technical background. Theories like Piaget's help them to understand general development and the access to logico-mathematical processes. They are for example able to see the interest of studies on the use of logo, the use of micro-computer games in normal schools.

For handicapped children, the situation is more difficult :

- we do not know the paths and gates of their development;
- research on this topic cannot be accomplished in parallel with ongoing education;
- any attempt to enhance the development of these children should not only have long or middle term goals, but also highly visible short term results;
- faillure in this last point will lead to the educator's reluctance and worse, to the discouragement of the child himself.

The role of a psychologist should be :

a) Make an analysis and a synthesis of what is wished for and what is needed by the handicapped child, and to translate these into a research and development frame;

b) As regard to specific problem, define the goal and the ways to reach it, and through a continuous interaction with research and development, contribute to the development of the most effective devices for particular purposes;

c) warn others of the serious mistakes to be avoided, particularly :

- any device should bring to the users an important benefit (quanlity and quantity) for a minimal new investment (physical effort, training). This is not the case for many devices (their conception or the ways in which they are used). Often a slow procedure and much physical effort simply leads to the same type of results as was quickly obtained previously by other means;

- a device, or program should correspond to a specific goal or a specific task and be appropriate to fulfil this purpose : it may even be harmful to include features attractive to the general public, which may quickly bore the child and teach him nothing;

- to use, with the same child, several of the communication systems that exist : written, short (oral) languages, etc.;
another frequent error being to use a particular communication system simply because it is available, without considering the child's needs or capacities;

- minspeak is probably a fantastic communication devices for adults in a social environment and with a social goal, but it would be foolish to use it as it is with young children;

- nowadays, it is very often seen that skilled research and development teams undertake their work on the basis of singular example, of fragmented requests which are not integrated in a general frame or process. This, from the user's point of view, is wate of their knowledge and work.

We could multiply such examples. On a long term basis, the gap will only be bridged by a comprehensive development, a multidisciplinary collaboration (psychologist, engineers, computers sciences), and by a carefull evaluation of the devices with a direct feedback to the research and development groups.

Of course bridging this gap is a difficult and wearing task in which we can only succeed by introducting educational programs for the people living with children in institutions.

The user and the devices

In acquired disabilities tremendous progress have been achieved during the last years. One of the most spectacular one is probably the fundamental change brought about in the life of tetraplegic people. In those acquired and generally traumatic handicaps, the aim of assist devices is quite clear, even if it is not easy to reach : restore a quality of life to compensate the handicap and allow activity again as well as social life. Moreover, some handicapped persons are involved in research and development, helpint to find the more efficient solution considering both requirements and physical possibilities. Most of these persons are able to give information on their needs and a fiable feedback on their experience with devices.

For handicaps resulting from neo-natal problems, from illness or trauma during infancy, the situation is completely different : the aim is not always clear and even the term of "user" is ambiguous. In this case, the introduction of increasingly sophisticated and performent devices which aim is to improve adaptation between machine and user comes in fact to a widening gap between the power and sophistication of assist devices and the demands of the users for such machines.

We come to ask WHO are the users ? How can we define THEIR requests ? On what experience and what knowledge do they ground their demands ? How do those often conflictual expectations integrate into the requirements of the optimal personal, intellectual and social achievements of the child ? How can those information be translated into a framework for device research and development ?

In the light of these questions, we have established a questionnaire. Its purpose is to make it clearer as to what is expected from an assist device or any communication substitute. A first survey has been made on a group composed of educators, institutional therapists, parents as well as persons who are not involved with such problems.

The first part of the questionnaire refers to the categories of users concerned (children, teenagers, adults, parents, institutions), and the handicaps concerned. At this level already it is shown that the demand for a communication device and the population to which such a device is meant for, does not meet an agreement.

The second part seeks the effective user's needs. To what function should the assist device stand for: play, educational, social activity, others ?

The third part more precisely refers to the external aspects of the communication device :size, weight, transportability, screen contents, necessary adaptation, price, others ...

Conclusions

The questionnaire has been conceived to help in seeing what the users' real needs are rather than to make a market survey. It is made of open questions such as "Do you think a communication device is useful ?", "For who ?", "When ?", "To what criterion should it correspond ?", "What purpose should it pursue ?".

The questionnaire is also composed of questions as to what should the global content be like. It ends with questions as to what imperatives, priorities and refusals are.

Preliminary steps have helped us in the conception of a communication project. A long term diffusion of the questionnaire should further lead us out of the battle field and perhaps in such a way as to set out conflictual elements into objectives.

A COOPERATIVE EFFORT: CEREBRAL PALSY RESEARCH FOUNDATION OF KANSAS (CPRFK) AND PROJECTS WITH INDUSTRY (PWI)

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ABSTRACT - This paper introduces and reports the current status of a federal grant project in which the vocational rehabilitation engineering resources of CPRFK are being enlisted for at least three prominent PWI projects in diverse geographical locations in the United States.

RÉSUMÉ - Cette communication présente un projet de subventions fédérales et donne un rapport de la situation actuelle. Les ressources en technologie de réadaptation professionnelle du CPRFK sont mobilisées dans au moins trois projets en collaboration avec l'industrie et ce, dans divers endroits des États-Unis.

INTRODUCTION

The Wichita Rehabilitation Engineering Center (REC) of the Cerebral Palsy Research Foundation of Kansas, Inc. has been given a 5-year federal research grant to develop and implement a project entitled "A Cooperative Effort: Cerebral Palsy Research Foundation of Kansas and Selected Projects With Industry Programs". CPRFK believes that PWI is one of the most innovative and cost effective programs in vocational rehabilitation. Thousands of mildly to moderately handicapped persons have been placed in productive, mainstream employment as a result of PWI efforts. It is intended through the grant to complement the placement strengths of PWI with comprehensive vocational rehabilitation engineering systems developed through the Wichita REC. The objective is to provide mainstream employment for the more severely physically disabled, who currently may be considered "non-feasible" for productive work.

The vocational rehabilitation engineering systems developed by the Wichita REC over the past 10 years include a functional assessment program called the Available Motions Inventory (A.M.I.) to measure objectively the functional capabilities of severely handicapped persons. Seven sets of A.M.I. test apparatus have been installed nationwide, plus one set is available as a mobile unit. In addition to the functional test capabilities, several successful placements of severely disabled persons have been made as a result of various adaptive devices and work site modifications at CPR's own Center Industries Corporation (CIC). CIC is not-for-profit "non-sheltered" manufacturing plant with 52,000 square feet of production and warehouse space that has been in operation since 1975. CIC employs approximately seventy persons, fifty of whom are physically disabled. All employees receive at least minimum wage plus a full fringe benefits package.

It is the specific intention of both CPRFK and PWI during this grant year to establish a pilot project in which our engineering resources will be enlisted for at least three prominent PWI projects in diverse geographical locations in the United States. Each of the projects are to supply at least two severely physically disabled clients who have been very difficult to employ. Each project also should identify at least one mainstream employer willing to cooperate with our PWI/CPR placement efforts.

METHODOLOGY

A survey was sent out by the Menninger Foundation Center for Applied Behavioral Sciences of Topeka, Kansas to eighty-six PWI programs currently in existence in the United States. This was accomplished by a written questionnaire to agencies briefly describing this project and soliciting from them descriptions of their placement techniques as well as a description of the handicapped population they serve. The questionnaire also addressed the issue of clients who have not been placed as a result of the severity of their disability.

The following summary of "preliminary" survey results gives an indication of the interest level in rehabilitation engineering support to job placement through Projects With Industry.

Total Surveys Sent:	86	
Total Responses	55	(64% of 86)
Total Responses Used	49	(57% of 86)
Engineering Support Desired	32	(64% of 49)
Engineering Support Not Desired	17	
Agencies that can identify cooperative employers	15	(46% of 32)
Total number of PWI projects involved with agencies desiring engineering support.	118	approx.

The handicapped population served by all responding agencies is broken down as follows:

Physically Disabled	36%
Mentally Ill	23%
Mentally Retarded	19%
Hearing Impaired	10%
Visually Impaired	7%
Other	2%

The four highest areas for target placement are:

Clerical	71%
Food Service	71%
Housekeeping	51%
Assembly	47%

The 49 responding PWI's estimate they will place 5,226 clients in FY '84. This is an average of 120 placements per program with a range of 13 to 500.

30% of those to be placed have five or more years work experience. Half the agencies expect their placement specialists to place 40 or more persons per year.

Based on the results of this survey, at least three PWI programs will be selected to proceed with the proposed research project. Selection criteria will be based on the diversity of potential placement opportunities for specific handicapped clients, and on the PWI organization's apparent interest in a long term cooperative relationship with CPR and the Wichita REC.

CURRENT PROGRESS

As of December 1, 1983, the following seven agencies have been contacted and are willing to begin with our project during 1984:

1. Merriam, Kansas - N.E. Multiservice Center
2. Washington, D.C. - Goodwill Industries of America
3. Bronx, New York - Aging in America
4. New Haven, Connecticut - Easter Seal Goodwill Industries Rehabilitation
5. Washington, D.C. - Human Resources Development Institute
6. Waltham, Massachusettes - Electronic Industries Foundation
7. Scottsdale, Arizona - Southwest Business and Industry Rehabilitation Association

A visit has been made to the agency listed first, the N.E. Multiservice Center, Merriam, Kansas. Three Kansas City employers have been contacted and offered engineering assistance for potential employees. Three clients of the N.E. Multiservice Center were administered the A.M.I. during late November.

PROPOSED ACTIVITIES

Once the cooperating P.W.I. agencies are selected and initial on-site visits are made with the agency staff, clients and potential employers, training criteria will be developed for P.W.I. staff and employer representatives. They will be trained in basic work site observation and description. A one-day training program at each P.W.I. agency is planned. This is percieved as a strategy to improve communication between CPRFK rehabilitation engineers, P.W.I. and their participating companies.

A brief milestone chart for 1984, beginning February 1, and ending January 31 is shown below:

	Months				
	0	3	6	9	12
Engineering Support to PWI Agencies	------	------	------	------	------
Select at Least Two More Agencies	------	------			
On-Site Visits		------	------		
Develop Training Criteria		------	------		
Develop Preliminary Cost Benefit Analysis				--------	--------
Develop Initial Feasibility Study				--------	--------

The results of this year's efforts will be presented as a joint article by CPRFK and PWI in the Wichita REC Tech Brief. Also, a cost benefit analysis of the value of rehabilitation engineering to the assisted agencies will be undertaken. This will contribute to a feasibility study to be developed during the last quarter of the year. Information to be included in the study will be listings of successful and unsuccessful applications of rehabilitation engineering and an analysis of which existing conditions and procedures contributed to the results. The feasibility of the project will be determined based on the current progress of the five year project and will include the successes, failures, suggested improvements, etc. It will include input from the workers, employers, and PWI staff. The project will be reported in the REC Annual Report.

Follow-up to determine employee performance on-the-job will be done during subsequent years' research. People will be placed on-the-job under the auspices of the PWI agencies identified this year. REC support through adaptive device design and fabrication, job restructuring, facilities layout changes, etc. will be provided along with appropriate follow-up to ensure success on-the-job. Ratios of clients successfully placed and performance against actual production standards will be accumulated in subsequent years to validate the concept of the interaction of research and service delivery rehabilitation agencies.

CONCLUSION

According to an October 25, 1981 article by James A. McCain of the Menninger Foundation entitled "A Jobs Program that Works", there are approximately 36 million (probably closer to 40 million in 1984) adult Americans disabled by accident, birth or chronic disease. A majority of these citizens are strongly desirous of meaningful, gainful, employment. This grant project is to determine whether employment of the disabled can be enhanced through the proven placement skills of an organization like PWI and the type of technical engineer support provided by the Rehabilitation Engineering Center of the Cerebral Palsy Research Foundation of Kansas, Inc.

ACKNOWLEDGEMENT

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PRODUCT DEVELOPMENT IN A RESEARCH AND DEVELOPMENT SETTING

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ABSTRACT - This paper describes the direction of research and development leading to the commercialization of the Alexis, an omnidirectional wheelchair developed at the Palo Alto Veterans Administration. It discusses the role of the research and development agency in promoting adoption of new devices, and mechanisms by which new technology moves from a development facility into the commercial world.

RÉSUMÉ - Cette communication décrit la recherche et développement qui a mené à la commercialisation d'un fauteuil roulant omnidirectionnel appelé Alexis par le Veterans Administration de Palo Alto. Il traite du rôle que peuvent jouer les organismes de recherche et développement pour promouvoir l'adoption de nouveaux dispositifs et mécanismes et pour ainsi permettre à des innovations technologiques de quitter les installations de recherche pour se tailler une place sur le marché.

INTRODUCTION

For the past three years the Veterans Administration Rehabilitation Research and Development Center in Palo Alto has been studying the possibility of omnidirectional powered wheelchairs. The project began with the hypothesis that an omnidirectional wheelchair could be developed from the recently patented invention of a mobile base which uses three independently driven omnidirectional wheels. Two vehicles using this concept have been developed in the three years since the Research and Development center began. The most recent of these vehicles, the Alexis, serves as the basis of a vehicle presently being developed commercially.

BACKGROUND

Development, in the sense that it is used in the context of a research and development agency, can be said to be the application of existing knowledge. In the field of rehabilitation this often takes the form of development of a device which will be useful to a person or persons with disabilities. But in a broader sense, development of a device must lead to the availability of that device, whether it is for only one person, or for groups of people with related disabilities. When more than a few of a given device are needed, there are no proven mechanisms by which the research and development agency can produce the devices, it will be provided by profitable commercial production and sales to either the consumer or to a third party. This being the case, the development agency must have a link between the development and the commercial worlds — that is, the development agency needs to follow a product oriented development path. This product oriented development will occur at three levels: 1) basic research is applied to define benefits obtainable from a device, 2) manufacturable devices are designed and developed, and 3) the widespread adoption of new methods and devices is promoted (ref. 4).

Development agencies have a great, but largely unrealized, potential influence over assuring the availability of assistive devices in the rehabilitation field. The development agency can realize this influence by orienting their work toward products. Product development in a rehabilitative research and development setting has key components in three areas (see figure 1). The development environment involves the roles that people assume relative to a project, the development philosophy consists of molding research and development tasks into product form, and concurrence of interest is the interest in a project shared between the research and development agency and the commercial world.

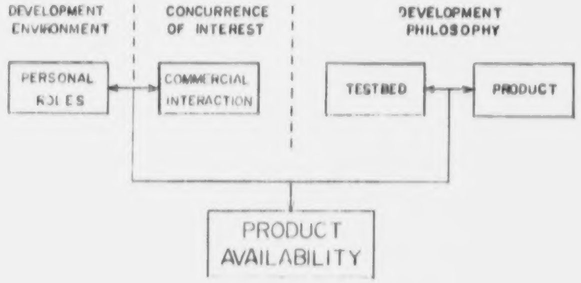

Fig. 1 Components of Product Oriented Development

DEVELOPMENT ENVIRONMENT

The existence of an environment capable of promoting product development to the stage of commercial interest is crucial to providing people who have disabilities access to devices which usefully incorporate recent advances in technology. The roles of people and their relation to a product are most important factors leading to the output of consumer oriented devices (ref. 1). The emphasis must be on the people involved and their roles in the development process. People should be allowed and encouraged to commit themselves to projects and treat those projects as their own. The people's commitment and sense of project ownership can, and should often pass beyond agency boundries.

The roles of "inventor", "implementor", and "organizer" must be filled to complete the usual development tasks, and to assure commercial development the additional roles of "hustler", and "champion" must be filled (ref. 2,3). A person may fill more than one of the roles throughout the duration of the project, or persons may switch or share roles, or drop in and out of the picture at any time. The people fulfilling these roles in the typical development environment (inventor, implementor, organizer) provide interaction with academic interests, fulfill clinical and funding responsibilities, complete a quality development process, and provide and implement conceptual ideas. The hustler and champion provide the project ownership necessary to move a product from a research and development setting into commercial development, the hustler providing and encouraging interaction with commercial interests, and the champion overseeing the transition to the commercial world.

The roles of implementor and organizer have been filled by a large number of people in the development of Alexis at the Veterans Administration. Less typical in the development process at a public research and development facility are the roles of champion and hustler. Yet these roles are specially important in an environment which includes no clinical responsibility or obligation beyond achieving funded tasks. As an example, an industrial liaison working at the Veterans Administration Research and Development Center has been involved with the development of the Alexis testbed from its start in Dec., 1982, and has been influential in promoting the device and hustling supplies, and cooperation of component vendors, both very necessary for continuing progress. His most important contribution has been the identification and encouragement of a venture capital firm to consider development of Alexis as a commercial product, and his willingness to work with a company to insure Alexis' future development and availability.

DEVELOPMENT PHILOSOPHY

The attitude of molding and integrating development tasks into the form of useable products is the basis of a product oriented development philosophy. Development proceeds along simultaneous paths, devices serving both as testbeds of new technologies, and as bases for manufacturable products. The application of a technology directly to a product both provides the ultimate demonstration of the technology's feasibility, and gives the most efficient use of funding. For example, the digital proportional-integral feedback controller, and MOSFET power devices implemented on the Alexis were funded by a wheelchair feedback controller grant (Veterans Administration — "Development and Evaluation of Wheelchair Feedback Controllers"), and demonstrated the feasibility of digital feedback control of wheelchairs. Integration of development tasks into useable products has been demonstrated well with the Alexis — its impact as the basis of a commercial product possibly being as important as the technologies it it is used as a testbed for.

The word "testbed" usually brings to mind an image of a crude, unfinished piece of equipment used in a laboratory, its usefulness limited to testing, evaluation and the generation of technical papers. However, a product development attitude implies attention is paid to manufacturability, durability, and reliability of devices being manufactured in quantities, the appropriateness of the device for a broad spectrum of consumers, and the overall finish of the device being appropriate for a consumer product. In Alexis this is exemplified by the attention paid to the seating system, the development of power bridges, and the chassis design.

CONCURRENCE OF INTEREST

The transfer of development to commercial interests, is in the best interest of both the public research and development facility, and the general public, and is also in the commercial interest of a company doing continuing development. This transfer is satisfying to the development facility in that technology developed by the facility will become available to those who need it — that availabilty being impossible for a research and development facility to provide. It also provides a convenient point to cease development of that device, freeing valuable resources for other projects.

This movement will necessarily involve personnel from the development agency, both in initially enticing a company to develop this device, and in providing in useable form a summary of the work that has already taken place. Typical involvement of development personnel with commercial interests is often limited to published documentation and correspondence. This limited form of involvement is likely to lead to limited success in effectively transferring development experience. More effective involvement would be in the form of indirect use of facilities, use of prototypes, sharing of personnel, etc.

The initial involvement of VA Alexis project personnel could be best described as the enticement of a venture capital firm to pursue the project. Among other things this took the form of tours of the development center for active company members, and videotape footage of the device as it currently existed. Crucial to the company's decision to go ahead with development was an agreement with several of the personnel who had been active in Alexis development to provide consulting services independent of the Veterans Administration.

SUMMARY

Figure 1 is a diagram of the key components of a product oriented development path. The Alexis omnidirectional wheelchair provides a good demonstration of an effective product oriented development path. The feasibility of several technologies were demonstrated on the product. Personnel filled the roles of champion and hustler, providing project ownership and interaction with the commercial world. The link to the commercial world led to a venture capital firm's decision to develop Alexis commercially.

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DIFFUSION OF INNOVATION IN REHABILITATION TECHNOLOGY: APPLICATION OF A THEORETICAL MODEL

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ABSTRACT - This paper discusses the use of a theoretical framework to identify and examine key barriers to the diffusion of innovative rehabilitation technology.

RÉSUMÉ - Cet article propose un cadre théorique pour identifier les barrières principales contre une diffusion efficace de la technologie pour la rééducation physique.

A cohesive theortical framework for the diffusion/dissemination of rehabilitation technology, particularly innovative technology has been absent from the literature. This paper will address this gap. The most thorough and most often cited framework in the general social science literature is the Diffusion of Innovation Model conceived and developed by Everett M. Rogers during the past twenty years. The Model states four elements of innovation diffusion: (1)the innovation, its sources and characteristics, (2)communication through channels, (3)innovation decisions occurring over time, (4)in the context of a Social System [4].

The model further states that adopters of innovations can be categorized as: innovators, early adopters, early majority, late majority, and laggards. Consequences of innovation decisions can be direct/indirect, intended/unintended, and desirable/ undesirable [4]. For ease of understanding, this theoretical diffusion model will be applied to one specific type of rehabilitation technology, assistive devices for persons with physical disabilities.

ELEMENTS OF DIFFUSION: THE INNOVATION

The major sources of innovation in assistive device rehabilitation technology will be discussed. The model states that five innovation characteristics are key to adoption: relative advantage, compatibility, complexity, trialability, and observability.

Relative advantage is often determined by cost and by third party reimbursement. These two factors are especially important in the case of assistive devices because disabled users often have fixed or limited incomes and are dependent on Third Parties, such as insurance companies and local, state, and federal governments, for equipment purchase.

Adoption of an innovation will also be affected by its compatibility with existing devices already in use, home/work environments, and other persons who interact with the user.

The complexity of the innovative technology also impacts its adoption. The familiarity of a device's control interface can facilitate its adoption. Complexity is particularly relevant when it comes to the time and effort required to learn the use of a new device. A user is more likely to devote more energy to learning a new complex device if the expected benefit is high.

If potential users have access to testing the device before purchase, then they could better determine its possible usefulness to them. Trialability can be achieved at Rehabilitation Engineering Centers (REC's) and Rehabilitation Training Centers (RTC's).

A fifth characteristic of the innovation that impacts its adoption is observability. The visibility of the effects of the innovative device can facilitate evaluative discussion among users and potential users.

ELEMENTS OF DIFFUSION: COMMUNICATION THROUGH CHANNELS

In the case of rehabilitation technology, mass media advertisements do not create knowledge of products. Possible reasons will be discussed. However, there are a few periodicals directed to persons with disabilities that do carry rehabilitation assistive device advertisements. Examples include Paraplegia News, Sports 'N Spokes, and Mainstream.

Because of this lack in mass media advertising, interpersonal contact among disabled persons and allied professionals becomes critical, not only to the innovation decision process (as it is in nearly all types of innovation decisions), but also to the information dissemination phase of the innovation adoption process.

A new electronic communication channel is ABLEDATA. ABLEDATA is a national computerized database containing information about rehabilitation products, and a network of Information Brokers who are distributed across the U.S. The network maintains product information on commercially available aids and equipment that are useful to persons with physical disabilities. The impact of ABLEDATA on the innovation diffusion process offers significant research potential.

ELEMENTS OF DIFFUSION: INNOVATION DECISIONS OCCUR OVER TIME

Knowledge about innovations is gained primarily through other users, ABLEDATA, media coverage of prototype research and development, periodicals directed toward persons with disabilities, therapists, physicians, and suppliers' catalogues.

Persuasion is the next phase in the innovation decision process. Disabled persons are often skeptical of new devices because of too many exaggerated promises and disappointments in the past. Suppliers must also convince the gatekeepers of information. These gatekeepers are physicians and allied health professionals who work with the physically disabled.

The decision to adopt an innovation can take several forms: optional, collective, authority, and contingent. Often disabled persons do not have an option to obtain a device they want/need because of limited funds and Third Party reimbursement policies. Examples of these four types of innovation decisions will be presented.

Implemenatation of an innovation decision is sometimes dependent on appropriate training in the use of the assistive devices. This is especially true with sophisticated innovative devices such as the Optacon.

Reinvention is also a major factor in the implementation phase of adoption of rehabilitation technologies. Reinvention may be defined as, "the degree to which an innovation is changed or modified by a user in the process of its adoption."[4] Examples will be discussed.

Confirmation of the innovation decision is attained as the device proves reliable over time. Dependability is more critical with regard to assitive devices because these devices are often essential for survival. Maintenance and ease of service are major factors in the continued use or disuse of rehabilitation technologies.

ELEMENTS OF DIFFUSION: IN THE CONTEXT OF A SOCIAL SYSTEM

Opinion leaders are usually the persons who determine the adoption of new technologies. Adopters of innovations can be divided up into categories. Innovators (first 2.5%) are venturesome, wealthy, and can afford to test unproven devices. They do not depend on Third Party reimbursement. Early Adopters (next 13.5%) are respectable, usually opinion leaders who are often politically active and likely to lobby for Third Party reimbursement. The Early Majority (next 34%) is deliberate and will probably not adopt until the device is reimbursed by Third party payers. The Late Majority (next 34%) of adopters is skeptical. They are often uninformed and more isolated from society. The Laggards (last 16%) are traditional and may never adopt an innovation unless it is absolutely vital to their survival.

Consequences of Innovation Adoption

Examples of desirable, indirect, intended consequences include: increased self-confidence, increased independence, and increased sense of control over personal space. Additional examples of all types of consequences will be discussed.

SUMMARY OF BARRIERS THAT IMPEDE DIFFUSION

Review of the literature, discussions with rehabilitation professionals from a wide variety of backgrounds, and application of this theoretical model have yielded the following summary of barriers.

Products are often not commercially viable because the market is ill-defined and presumably small. There is a dearth of demographic data and information on consumer preferences/needs. Needs assessment is difficult when a unique device that does not replace an existing device is introduced. Specific devices have often been developed for specific uses and users; this means that little economies of scale are generated to recover large R&D investment and development costs.

Third Party payers effectively purchase most of the devices. Reimbursement usually depends on a product being prescribed as "medically necessary" or vocation specific. [1]

There is virtually an absence of prototype evaluation and cohesive evaluation protocols or standards. Devices often have limited usefulness because they were designed without user input during the design process.[3] Devices are designed for disabled persons by insufficiently educated able-bodied engineers/designers. Data on desirable user and device characteristics do not exist. Utility of the device must be demonstrated in the development process so that additional resources can be efficiently allocated.

Maintenance and repair are critical factors to the successful use of a new device. Access to convenient servicing and replacement parts is especially important to persons with mobility/communication impairments.

Manufacturer's Liability Insurance Requirements are greater because injury to a disabled person can have a greater impact on health and independence. This additional expense and liability can inhibit new start-ups.

The Device Patent Process is expensive, requires a lawyer, and is time consuming. Patents and legal fees can increase the costs of the end-product, and often become outdated quickly because of rapidly changing technology and the difficulty in proving patent violations.

This paper has helped identify key barriers in the diffusion of rehabilitation technology.

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TECHNOLOGY PUSH/PULL AND THE QUALITY AND USEFULNESS OF AIDS

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ABSTRACT - Innovation and evaluation of products for the handicapped are closely related: successfulness of innovation is strongly dependent on how evaluation of the quality and usefulness of the innovative product is planned. The paper goes into the fundamental back-grounds of research into quality and usefulness and concludes with considerations for intensified international cooperation.

RÉSUMÉ - L'innovation et l'évaluation des produits pour les handicapés sont liées étroitement: le succès d'une innovation dépend beaucoup de la façon dont est planifiée l'évaluation de la qualité et de l'utilité du produit nouveau. La communication aborde les fondements de la recherche en matière de qualité et d'utilité et conclut à la nécessité d'une coopération international accrue.

Introduction

The impact of technology, wich has taken place in the last years, on the daily life of people is impressive. In a quite different way, there has been also a strong impact on the life of handicapped people. This does not imply that the gap between non-handicapped and handicapped people has been diminished. On the contrary, technology has given a strong increase of possibilities in mobility and communications which cannot be used by the handicapped people to the same extend as the non-handicapped people are using it. In general, it can be said that this gap can be caused by the following reasons.

- Technological products are not designed with potential use of handicapped people in mind. Examples: House appliances, Public Transportation and a special example is the development of screen-oriented texteditors which cannot be used by blind programmers.
- Adaptation of new technology to the needs of the handicapped is a difficult problem from the commercial and scientific point of view. Innovation and product development in rehabilitation has to deal with a quite different environment.
- There is a lack of professional effort in product designing: small series and single products seem to approve that the design proces has to be done less thoroughly and with less quality than for the large consumer market. This might be caused by insufficient education in this field.
- Feedback of product usefulness is not provided in the same way as for consumer products.

More remarks like the above can be made. However, we think that much can be explained by using models for the innovation proces and for research in quality and usefulness of aids. This paper will deal with these models and a final paragraph gives an overview of the situation of these subjects in The Netherlands and preferred relationships to activities in other countries.

A model of the development and provision of aids

A model of product development and provision of aids is basically simple and valid for most developed countries (fig. 1); adaptations have to be made for various countries.

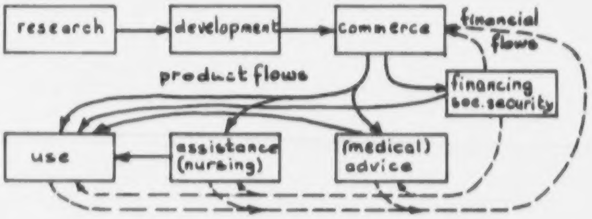

Fig. 1: Model of innovation and provision of aids

The most important observation in this model is that the financial flow and product flow have different paths: thus, the regular market mechanism for consumer products does not exist. Furthermore, innovation and the provision of aids needs a very good communication between the distinctive elements. Unfortunately, it is seen that this information transmission does not exist or is insufficient. It is essential that an analysis has been made of the existing pathways of a certain product before starting research on that particular product. The research and development activity (innovation) can be started in two different ways; first by a need which exists at the users (technology pull) and secondly by suggesting applications from the viewpoint of modern technology (technology push).

In the available literature, much attention is paid to how an innovation project should run and who should be involved. Less attention is paid to the effect and the importance of research into quality and usefulness of aids. Research on quality and usefulness has to take place at the end of an innovation project, but should also be the first step in a project which aims on improvement of a certain product.

Research on quality and usefulness of aids

Comparative product testing is mostly dealing with (technical) quality and economical aspects of products, i.e.: energy consumption, reliability, safety, costs, etc. Basically, quality involves the "average" properties of a product as should be experienced by a large test-group of users with a limited variability within the user-group. Especially in the field of products for the handicapped it is known that general characteristics of a product does not guarantee or will make it expected that a product will be actually useful. Thus, research into the usefulness of a product should imply the degree of satisfaction that a product can contribute to the solution of users needs. As needs will vary individually, it may be concluded that a general number or a degree of usefulness can never exist. In practice, a clear distinction cannot always be made between quality and usefulness.

A general model for research in quality and usefulness is given in figure 2.

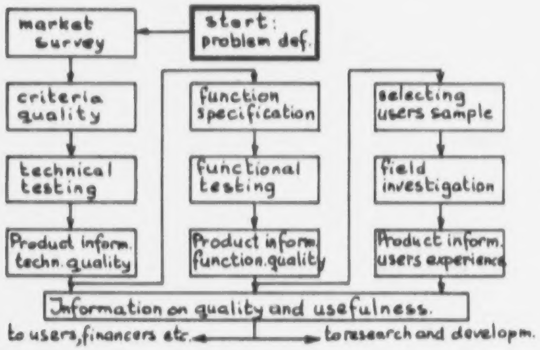

Fig. 2: Scheme for quality and usefulness research

In the figure it is seen that three types of product information results will be gained: a) technical quality data, b) functional performance data and c) user experience based data. A crucial matter is the specification of the (supposed) function of the product to be investigated. According to the definitions of the WHO on impairment, disability and handicap, one has to specify on which level the product should function:

A: The aim of a product can be the partial restoration of a certain impairment of a person. Typical examples are an armprosthesis and a hearing aid. Testing can be done for a great deal in a laboratory situation. Field studies are still required to estimate side-effects caused by using the aid.

B: A product might be designed for use on the level of disability compensation: Due to an impairment, some daily functions cannot be done anymore. Other modalities are used to perform the task. A typical example is that if vision is insufficient for reading, it might be useful to read text in braille coding. In this case it is also possible to do the testing mainly in a laboratory situation, but only if the tasks to be done can reasonably simulated in the laboratory. Field studies are necessary for the same reason as stated at A).

C: If impairments are very severe, and solutions cannot be found on the levels A) and B), it might have sense to find out if a compensation for the resulting handicap can be given. To illustrate this: a person who has no acceptable possibilities for travelling and has a lack of social contacts could find some compensation in having additional recreational possibilities at home. It will be clear that testing that type of "products" and provisions can only be done with a field evaluation approach. It is difficult to determine the functional specifications.

The results of this research will immediately lead to improvements of a "repair"-type by the manufactures and works preventive. It gives also excellent starting points for product renewal and the set-up of development of new products: thus, it causes a strong technology pull. At the other side, research in usefulness is essential to guide the technology push. Proposed new-technology-based-aids, as for example speech technology, is for many people too futuristic, that they can make an imagination of the real impact to their live. Studying and reporting the usefulness of this technology in pilot-projects will give a potential user better insight in the possibilities.

International cooperation

The research into quality and usefulness of aids is hampered by two points: first, there is a lack of a good methodology and organizational systems to execute this research and secondly, this type of research is very expensive. The first point could be solved by stimulating various disciplines to cooperate on a scientific level with the goal to develop a methodology and practical experience. It might be of interest to set-up an international workshop on this subject.

The second point is suggested to solve in an international cooperation: product reports of one country can be usefull in other countries too if some precautions are taken into account. These precautions are that the same terminology has to be used, all available products in a product-group in the cooperating countries has to be studied, and cultural/social differences have to be taken into account. The Nordic countries did succeed in such a set-up. The Netherlands could possibly join the Nordic set-up: introduction of the Nordic classification is prepared.

Concluding remarks

International cooperation on product evaluation is dependent on the various national efforts in innovation in the field of rehabilitation and aids (1, 2, 3). Unfortunately, the background of these national efforts is for a great deal the supposed economic and industrial effects. As product evaluation results are the basis for a good description and definition of the needs for a product, it is also influencing the market. It is hoped also that the level of commercial activity an international cooperation will develop, in spite of competition.

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SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 16

INDEPENDENT LIVING IV - ADAPTED AIDS/
VIE AUTONOME IV - AIDES ADAPTÉES

A NEW REACHER

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ABSTRACT - This paper describes a newly designed reacher for wheelchair-bound persons with weak grasp and small range of finger motion. The reacher has a specially designed grasping mechanism which is activated by a hand-operated ratchet system. This multiplies the user's grasp and reach and has many vocational and personal applications.

RESUME - Ce texte décrit la conception d'un appareil permettant aux personnes en chaise roulante et restreintent dans les membres supérieurs d'atteindre des objets normalement hors de portée. L'appareil comprend un méchanisme de type rochet à cliquet pour la fermeture de la pince. Ceci rend l'utilisation de l'appareil plus facile et moins fatiguante.

INTRODUCTION

In the field of rehabilitation, it is a well-known fact that each case is individual, and that no solution will be the same for everyone. It is not uncommon to see cases where no commercially available aids can appropriately solve the problem. In dealing with such a case, one has either to modify an existing device or design a new one to suit the person's needs. This paper presents such a situation.

CASE HISTORY

The young person, following an illness, has only the use of her dominant arm, and is mobile only in an electric wheelchair. The best position in which her arm functions, with respect to stability and strength, is as follows:

1. The forearm is pronated at 20°.
2. The wrist is flexed volarly about 20° and ulnarly approximately 40°.

In this position, the hand is able to make a full total grasp hold. However, the strength of the hand is limited due to some residual ulnar nerve motor loss. Finally, strength occurs mainly in the thumb, index, and second fingers.

While working as a pharmacy technician, this person was straining to reach the upper shelves from her wheelchair. There was a concern that back problems could develop in time, due to the constant strain. Furthermore, a lot of the items were out of her reach, making her more dependent on others in her job at the store. Various commercial units were tried out, but none were strong enough or useful enough to solve the problem. Firstly, because she cannot use her hand in a normal manner, the design of the handles of the commercial reachers prevented her from using her maximum strength position. Secondly, because of her residual weakness, the weight and fragility of the objects which she had to handle, she was unable to grasp, hold, and lift at the same time. Finally, none of the reachers tried were designed to lift heavy objects. Thus, it was felt that a reacher, especially designed for her, must be made.

THE REACHER

The criteria set down in designing the reacher are as follows:

1. Customize the handle to suit her hand function.
2. Enable the grasping of objects weighing as much as 2 kg. with a minimum of force.
3. Have a locking mechanism in the grasping position so that strength can be directed towards the lifting of the object.
4. A length of at least 24 inches.
5. Provide some support at the arm for lifting heavy objects.

To grasp an object, the handle is pulled reciprocally. A gear reduction and a ratchet-type mechanism achieve a force multiplication factor of 2 (see figure 1). An arm support is attached to the reacher for lifting heavy objects. The handle is shaped after the person's hand for better grasp and ease of use. The ratchet mechanism is released by a simple push of the thumb.

For the clamp itself, it was felt that, in order to minimize the strength needed to grasp, we had to maximize the surface of contact between the clamp and the object. One way of doing that is to make a clamp that acts like a hand. The hand automatically takes the shape of the object. Use of non-slippery rubber would also help by acting much like the skin does. The clamp is made with three fingers, one in opposition to the other two. They are positioned to interlace on closing. Each finger is made up of four articulations, activated by cables. Figure 2 shows the principle of the mechanism. The cable pulls the last articulation and passes eccentrically from the axes of rotation, creating a moment at each articulation and making the finger flex. Since the cable is fixed only at the last articulation, the finger automatically takes the shape of the object. To return to neutral, the pulling cable is set up to act in opposition to another one placed on the other side of the axes of rotation. The tension is strong enough to extend the finger, but is still small compared to the action of the user. The hand has an opening capacity of 4½ inches, and can enclose a 1 inch diameter cylinder. The inside of the fingers are covered with rubber, to increase friction. This is especially useful when glass objects are handled.

Trials with the user confirm that this kind of reacher could help her a lot. Following the assessment period, when some modifications may be made, the reacher will be given to this girl to keep, and steps will be taken to make units available to larger groups of similarly disabled individuals.

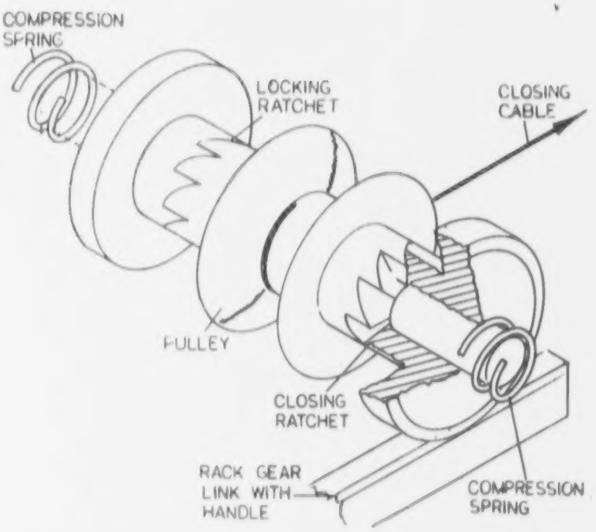
COMPRESSION SPRING
LOCKING RATCHET
CLOSING CABLE
PULLEY
CLOSING RATCHET
RACK GEAR LINK WITH HANDLE
COMPRESSION SPRING

Figure 1. Gear reduction and ratchet mechanisms.

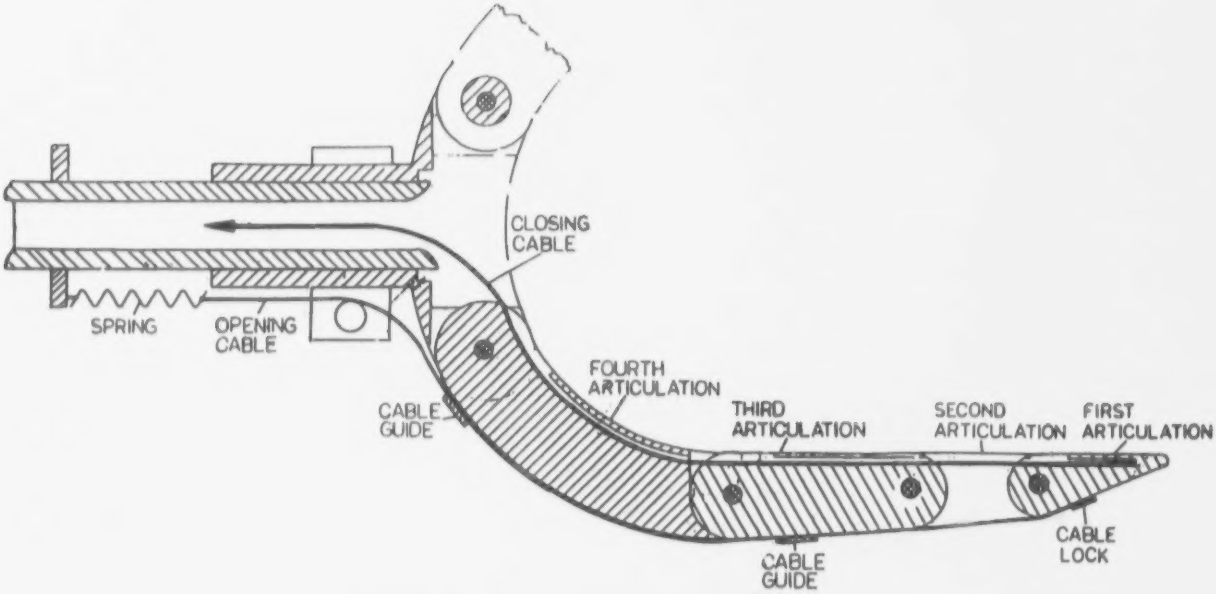
CLOSING CABLE
SPRING
OPENING CABLE
FOURTH ARTICULATION
CABLE GUIDE
THIRD ARTICULATION
SECOND ARTICULATION
FIRST ARTICULATION
CABLE GUIDE
CABLE LOCK

Figure 2. Detail of grasping mechanism.

A LIGHT DUTY POWERED LIFTING AID (REDelift)

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ABSTRACT - The inability to lift moderately weighted (2-10 kg) objects can seriously limit employability and reduce independence in the home. This paper describes a mobile powered lifting aid which can elevate goods to work height or transfer foods in the home kitchen.

RÉSUMÉ - L'incapacité de soulever des objets modérément lourds (2 à 10 kg) peut limiter sérieusement les chances de trouver un emploi et réduire l'autonomie à la maison. Le présent rapport décrit un élévateur électrique mobile qui permet de lever des objets à hauteur de travail ou de déplacer de la nourriture dans la cuisine.

INTRODUCTION

Through accident or disease many people lose back or upper limb strength. This weakness can greatly limit the ability to lift even moderately weighted objects (2-10kg). In the work place this may mean the inability to lift parts to work station height thus limiting employment. In the home, particularly the kitchen, foods and crockery must be lifted or lowered between countertop and oven or refrigerator. Such foods can be extremely hazardous due to their weight, temperature and the presence of hot liquids.

Special techniques can be used for sliding objects that cannot be lifted but this often requires special appliances such as countertop ovens. Space and monetary considerations are often a limiting factor.

Devices are presently available for lifting light objects. An assortment of reachers (1,2) can be used for retrieving papers or small items but with arm weakness these reachers are of limited value. The next largest lifting aids are hoists for lifting people. There are virtually no light-duty powered aids for lifting medium weight objects. The device described here was designed to fill this gap.

DESIGN

The lifting device (REDelift*) went through many changes during its development. Originally envisaged as a fixed in place, hand or power operated lift with a swing out arm to support the load (3), it is now a small, free-wheeling, battery powered elevating platform (see fig.1). Hand operation was considered unsuitable for the target user group. Mobility of the lift offers wider use of a single unit as it can be used throughout the home or place of work.

The lifting column consists of two diagonally opposed aluminum angles, two steel guide rods, end plates and a base equipped with four castors. The base design allows the table to be positioned adjacent to the work area while maintaining a broad base of support. A gear-motor, mounted under the table has a pinion that engages a rack on the column. This drive system was chosen over cables, linear actuators, or screw jacks because of its simplicity and the greater range of travel available. A gel battery supplies power through an appropriately located switch. The column is covered with formed ABS to give a pleasing and easily cleanable surface. The table is also ABS but is covered with a commercial hot pad as ABS has a forming temperature lower than common cooking temperatures.

OPERATION

The lift is first rolled adjacent to the work area. It is then adjusted to a suitable height and the object is transferred to the lift table. The lift is then rolled to the offload location, the height is adjusted and the object unloaded.

DISCUSSION

The REDelift is presently in the prototype stage with full home trials to begin shortly. Following these trials and any required design optimization, the lift will be available locally at nominal cost through a special aids program. If sufficient interest exists to warrant commercial production, this will be considered. If production is not practical then full construction drawings will be made available upon request.

More details will be available in Ottawa.

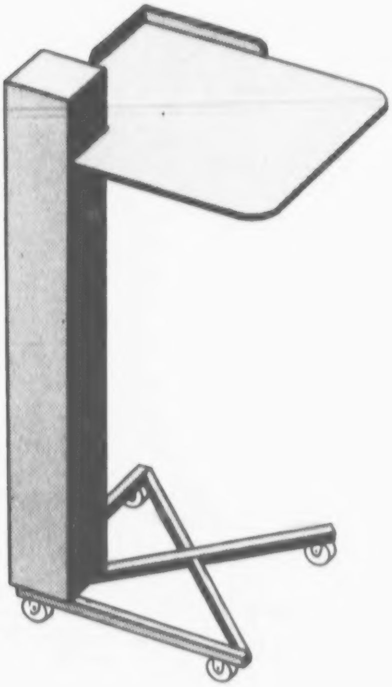

Figure 1

CONCLUSION

The lifting aid described here is a needed addition to the pool of equipment available to disabled persons. It can open avenues of endeavour to suitable individuals who have previously had limited interaction with their surroundings.

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   Report to the Dept. of Mechanical
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   Red River Community College
   Winnipeg, June 1982

* Rehab. Eng. Dept. lift

REHABILITATION ENGINEERING AT O'DONOGHUE REHABILITATION INSTITUTE: VOLUME II

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ABSTRACT - Three devices developed at ORI are presented. The first is an adaptation to a toy robotic arm. The second is a modification of the high quadraplegic feeder developed at the Northwestern R.E.C.. The last device is a remote volume control for stereo systems.

RÉSUMÉ - L'ORI a élaboré trois dispositifs que nous vous présentons ici: le premier est une adaptation à un bras de robot jouet; le deuxième, une modification de l'alimenteur de tétraplégique profond, élaboré à la REC de Northwestern; et le troisième, une télécommande de volume pour chaîne stéréophonique.

The ORI Rehabilitation Engineering department is service oriented. As problems needing technical input arise, the staff at ORI and nearby hospitals ask RE to modify or construct special devices. Three such devices are presented here.

Toy Robotic Arm Modification:

A Radio Shack "Armatron" (Radio Shack #60-2364) was purchased for play by a young boy with an incomplete C 1-2 spinal cord injury. The "Armatron" is a motor-driven mechanical arm with 6 degrees of movement. These movements are finger grasp/release, wrist rotation, shoulder adduction/abduction and flexion/extension of the wrist, elbow and shoulder.

The six movements are controlled by two X-Y joysticks, each with rotary knobs to control a third movement.

The client could operate the joystick in the X and Y directions, but unable to twist the controls. The twisting motions controlled finger grasp/release and wrist rotation.

Two Y direction slide controls were added as substitutes for the twist control as shown in Photo 1.

Presently the device is used only occasionally, due to a heavy occupational therapy workload.

Feeding Device for High Spinal Cord Injured Clients:

This feeder is a refinement of a feeder developed at the Northwestern R.E.C.; and presently available through Fred Sammons, Inc., Catalog (#BK-1244).

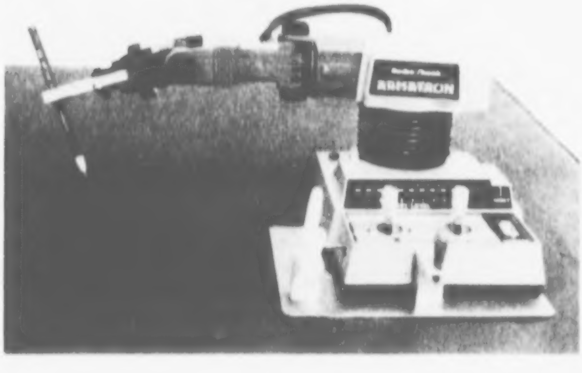

PHOTO 1

PHOTO 2

Functionally, both feeders operate identically; the user bites on the handle end of a spoon or fork to catch a bite of food. By placing the utensil on a swivel blade, the user can move the utensil to bite the food.

As shown in Photo 2, the feeder concept has been retained while adding a number of features:

(1) adjustable height to accomodate different table heights. (The height adjustment mechanism has been simplified from the version shown.)

(2) Drilling of the plate and sandwich holder is unnecessary.

(3) Lighter weight and greater visual appeal.

Several versions of this feeder have been made, including one that attaches to a lapboard.

It is possible to construct a folding feeder for easier travel.

Remote Volume Control:

Several years ago, the BSR Corporation developed a system allowing remote control of lamps, including brightness, and control of appliances by units transmitting and receiving signals impressed on the A.C. power line.

When used with a BSR lamp module, the circuit shown in Figure 1 allows remote volume control of stereos and other audio devices.

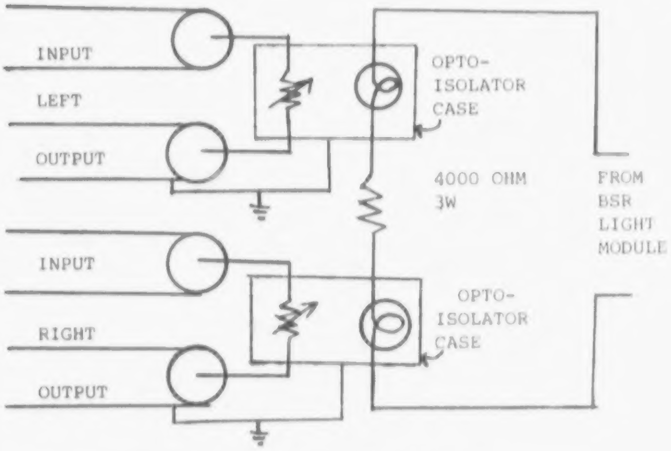

FIGURE 1. REMOTE VOLUME CONTROL

Notes:

(1) Circuit is installed in pre-amp to amp connection, or tape monitor loop of stereo.

(2) The optoisolators used were Vactec, Inc. #VTL9A11, 12 volt incandescent-photoconductive modules. Different voltage modules can be ordered from other manufacturers.

(3) For best hum immunity, mount circuit in grounded metal box.

To turn on and off the stereo, it is suggested the stereo be plugged into a BSR appliance module.

When using a standard controller, it is suggested the user perform the following sequence:

(1) Turn on the volume control lamp module

(2) "dim" the lamp module (this will prevent the stereo from coming on at full volume)

(3) Turn on the stereo appliance module.

When finished, the user should turn off both the volume control lamp module and the stereo appliance module.

Manufacturers of the newer environmental control systems could program the units to store the preferred volume and turn the stereo on to this volume with one activation.

The circuit could be modified to allow independent control of each channel or radio tuning.

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A NEW LIFT ASSIST AID

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ABSTRACT - A lift assist aid is described which helps individuals with weakness in their legs to stand up from a sitting position. It represents an improvement over existing models because of its greater lifting force and because of its specially designed lifting motion. The size and weight of the lift assist aid make it conveniently portable.

RÉSUMÉ - Ce texte décrit un appareil d'assistance permettant aux personnes ayant des faiblesses aux jambes de passer de la position assise à la position debout avec moins d'effort. Il représente une amélioration par rapport aux modèles déjà existant quant à la force verticale plus importante qu'il exerce et par sa portabilité.

INTRODUCTION

Many wheelchair bound persons could walk if they were fitted with the proper appliance and if they could start from a standing position. Unfortunately, these persons usually need assistance to stand up because of weakness in their legs and/or arms. This dependence on someone to assist them, greatly reduces the amount of walking they do. A way to overcome this problem would be to make a mechanical device which would give the needed lifting assistance. Several designs have already been tried, with some limited success. However, problems still remain to be solved.

EXISTING LIFT ASSIST AIDS

In 1977 Henshawe and Agarwal (1) reported on an hydraulic lifting wheelchair for paraplegic patients, with a Salford type walking appliance. Although the device works quite well and lifts the user completely, bringing him to a full standing position, its weight and size makes it too cumbersome to be portable. Thus, its use is confined to the wheelchair for which it was made. In 1979, a commercial electric lifting cushion was reported by Staros and Peizer (2). Again, in spite of full lifting capabilities, the device lacks portability which is essential if it is to be used on the wheelchair, on the user's chair at home, and in other situations. Finally, we should mention that a portable spring loaded lift assist aid is commercially available (3). Unfortunately, this device does not provide enough lift for the majority of users.

RE-DESIGNING THE LIFT ASSIST

The situation described in the previous section raises some questions which should be answered prior to embarking on the design of a new lift assist:

1. What should be the maximum size and weight of the device?
2. What type of movement of the seat is optimum to lift a person to the standing position.
3. Should the device lift the full weight of the user and, if not, what lifting force is required?
4. How many times per day would a person make use of such a device?

To answer these questions, an analysis of the standing-up motion was made, and discussions were carried out between Rehabilitation Engineering and Occupational Therapy personnel at the Royal Ottawa Regional Rehabilitation Centre. To analyse the movement, we used videotaping, goniometers, and a force plate. The videotaping was used to obtain an overall view of the motion. The goniometers provided us with precise measurements of hip, knee and ankle movement. The force plate gave us a measurement of how the weight is transferred to the feet during standing up.

An example of the results obtained in the analysis is presented in figure 1. The goniometers show that in the initial part of the movement only the hips are in motion, flexing in order to shift the weight of the upper body forward. At the peak of hip flexion, and going to extension, the knees start to extend in order to lift the body. At the same time, the ankles start to dorsiflex. The ankles reverse to plantar flexion in the middle of lifting up. Thus, the ankles start at an angle of 90° and end at an angle of 90°. The force plate data shows a small burst of vertical force when the person leans forward, prior to standing up. This is followed by a rapid increase in vertical force, as the subject transfers weight to his feet. When approximately 3/4 of body weight is reached, the knees start to extend. Body weight is reached while the subject is lifting his body. Initially, the arms take 1/4 of the body weight, which is slowly transferred to the legs as the subject straightens up. It is mainly this last 1/4 of body weight which many persons have difficulty dealing with. Thus, we don't need to supply a lift equal to the full body weight. A lifting force of 1/4 of body weight is sufficient. The videotape recording shows that the buttocks move in a circular trajectory with the knees at the centre. The lift assist seat should, therefore, have the same motion. Thus, the whole of the seat (front and back) must lift while the seat is being rotated forwards. In the fully extended position, the seat should have lifted 4 inches in front and at least 10 inches at the back.

The specifications set down for the seat are, then, as follows:

1. The seat should measure 16 x 16 inches and be no more than 3 inches thick.
2. The weight should be no more than 15 pounds.
3. The motion of the seat should be a vertical displacement and a forward rotation. The force which causes this motion should be at least 50 pounds.

Considering the weakness of the user, it is expected that the lift assist would be used no more than 7 times in any one day.

A prototype of the new design is shown in figure 2. The motion is produced by an axle and a sliding mechanism. The lifting force is achieved by a passive spring. The frame and most of the parts are made out of aluminum, for strength and light weight. The seat can be locked in the folding position to enable the user to carry it with him. Because of its small size and light weight, the device is easily portable.

CLINICAL EVALUATION

The lift assist aid was tried on patients within the Royal Ottawa Regional Rehabilitation Centre who, found it very helpful for standing up. Following a careful assessment, and minor modifications, the lift assist will be made available to a larger number of clients.

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2. Staros, A., Peizer, E. (1979) Veterans Administration Prosthetics Centre Report. Bulletin of Prosthetics Research, BPR 10-32, Fall pp, 441-500.

3. NOMEQ catalog 1983/4 Wasford Mills, Ipsley Street, Redditch, Worcestershire p.33

ACKNOWLEDGEMENTS

The assistance of other Rehabilitation Engineering and Occupational Therapy personnel, especially Mr. Louis Goudreau and Ms. Anne Gaylard is acknowledged with gratitude.

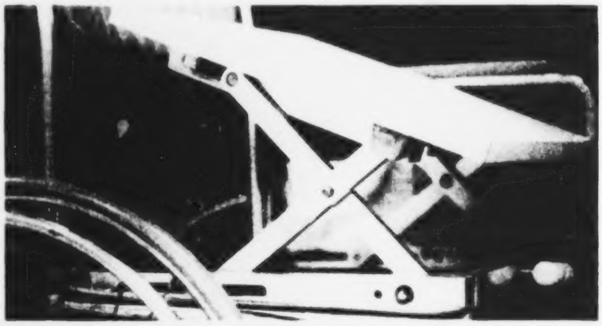

Figure 1. New Lift Assist.

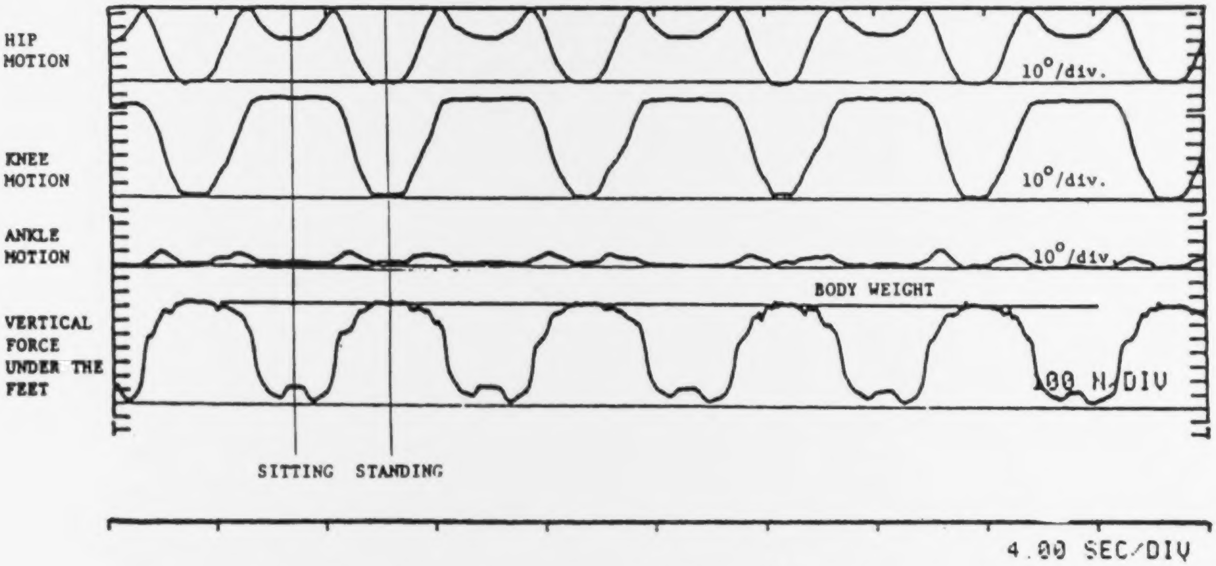

Figure 2. Limb angles and vertical forces in standing-up.

CLOTHES ADAPTED FOR PEOPLE WITH PHYSICAL HANDICAPS OR OTHER SPECIAL NEEDS

Nell Schilder, Vice-President on the Rise Association Inc.
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ABSTRACT - Everyone has the right to Look Good, Feel Well and be as Independent as possible, by wearing garments, which are fashionable, comfortable and have, where necessary, hidden adaptations to assist in the rehabilitative process.

RÉSUMÉ - Chacun a le droit de bien paraître, de se sentir bien et d'être aussi indépendant que possible dans le port de ses vêtements, lesquels sont à la mode, confortables et ont, si nécessaire, des adaptations dissimulées pour aider le processus de réhabilitation.

What is a housewife and dressmaker doing at a conference on engineering? Rehabilitation engineering no less. Well the Webster dictionary defines engineering as: the science by which the properties of matter and the sources of energy in nature are made useful to man in structures, machines and products. Now **that** makes sense and that is how it all started, way back, when certain "properties of matter" twisted by certain "sources of energy", turned into lovely strands, which, when combined in certain ways by different manipulations through the use of simple machinery, turned into very useful "products". In other words, this housewife was (and is) a spinner of yarns. Starting with natural fibres, fed into a spinning wheel, then knit or woven, she turned these fibres into fabrics.

Fabrics can be used to make garments. We all wear them, we all need them. But not all of us can put them on ourselves. In fact a great number of us cannot dress ourselves completely or not at all. Some of us have to dress those, who are unable to do so themselves.

Regular clothes inhibit rehabilitation. It is near impossible for many to manipulate buttons, hooks and eyes, backclosures etc.. To put garments on, up or down, is out of the question. So, how are we teaching independence and selfcare, if something as basic as lowering or pulling up of underwear and slacks is an impossibility?

It was this very basic need of an independent minded handicapped youngster, that started the work of ON THE RISE. Twelve years old she was, unable to speak, limited in the use of her hands. She needed to be helped to go to the washroom and did not like that. Being also mentally handicapped, she did not quite understand how to slip the waistband of her pants over the bulging bodycast (or more officially a prosthetic device). Besides, her fingers could not hold onto the garment. How to work this out? Decorative large beltloops, into which she could hook her better finger, and elastic in the back of the jeans did it in this case.. As it turned out, it was one of the less difficult problems to solve. Since that day, we at On The Rise have learned a lot about this aspect of engineering: engineering a bra, a bathing suit, snowpants and many other garments.

Besides the obvious, such as the replacement of buttonclosures by Velcro, while retaining the button-and-buttonhole look, there is the other side of the coin. The impossible backclosures of brassieres; the near impossibility of putting spastic arms in sleeves; the child that starts school and cannot help him- or herself in the washroom; the prosthetic device that rubs the skin raw; and beyond all this, the right to look good fashionable, and in particular for the young adolescent the need to belong to the undefinable nameless-sameness-group of the young adolescent.

Our work is fascinating and time consuming. It can be exhausting for the customer, because there is much trial and some error. At On The Rise we are a rather persevering lot and have found our guinea-pigs, the customers of the same ilk. That is rather fortunate, because it is the only way we can achieve anything. There is not much to draw information from, other than some good books. We have gratefully used Anne Kernaleguen's book, as well as the book by Evelyn Kennedy of the PRIDE Foundation in the USA: " Dressing with Pride".

But when it comes to practical work, not two cases are alike and it is back to the drawing board or the pattern department, acutally both.

We have developed a standard line of clothes, from underwear to outerwear, which looks like everybody's garments, but have hidden adaptations to promote easier dressing. What is more, we have a way of sizing them individually, as many of our customers have figure problems in addition to or because of their physical handicaps. These garments are available from coast to coast by catalogue.

The adaptations are not necessarily our inventions. The aforementioned books and other publications and ideas have been helpfull as well as the suggestions we receive from our customers. However, it became very clear very soon, that no two look alike problems are actually the same. The cause of the problem or the individual make-up of the customer usually requires changes to every "standard" design.

All our adapted designs have been worked out and implemented with and for a person with a very special need. So many have so little use of hands and fingers or have figures totally out of proportion. Permanent wheelchair occupation does not do much for the shape of the body. Some women are very conscious of the fact that their hips have spread. A specially designed two piece bathing suit, which in addition to hidden zippers (for easy access) also has a little skirt to seemingly hide unwanted bulges, has become quite popular.

Once in awhile we got what we thought to be a brilliant idea and use it to make a particular garment. It never worked. We quickly learned that there are more than enough actual life situations to keep us busy and to forget this do-your-own-thing-engineering.

We make slacks which do not have to go up or down for washroom use or are designed to be protected against soiling. Dresses which can be pulled and kept forward, without having to hold them up or out of the way while toiletting by two simple tabs in the inside sideseam. Some of our clothes open out completely, so a person can be put on top of it before being zippered up or "Velcroed in". Some of our outerwear is designed not to get caught in wheelchairwheels. We design bibs to match garments. This decidedly beats having a towel knotted around the neck. Etcetera, etcetera.

More and more are we getting involved in designing specialty items for specific problems. We have been involved through requests from staff at hospitals and rehabilitation centres to supplement their work.

We have designed and made shoulder support garments for stroke patients. Todate this has been quite succesful, but needs ongoing work and modifications, so it can possibly have a broader use.

We executed several designs for a protective garment for amputees to be worn in prosthetic devices, incorporating regular underwear.

Generally the emphasis seems to be shifting towards specific-problem-solving-clothing, away from the "standard" catalogue items. It is too early to tell where the work of On The Rise will be of the greatest importance. Our aim is: Fashion, Comfort, Independence. When a mother triumphantly tells us that her first grader (in braces and with two very short arms) now is totally independent, thanks to On The Rise garments, and that, besides, he is happy, because he looks just like his big brother, we feel that we have reached our goal.

We have to overcome many odds. We lack manpower, financing, machinery; all ingredients for succesful engineering. We try to make up for this through love, time donated and hand and legwork. We would like you all to know and spread the word that On The Rise is available and willing to look at and try the unusual. it does not always work, but often enough to make us persevere.

(On The Rise Association Inc. is a nonprofit corporation and registered as a charitable organization)

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(PRODUCTION AND DISPLAY FACILITIES AT
666 KIRKWOOD AVE. OTTAWA TEL.: 722-2561)

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EVELYN KENNEDY: Dressing with pride I. P.R.I.D.E Foundation.
1159 Poquonnock Rd. Groton, Conn. 06390

DRIVER ASSESSMENT UNIT FOR DISABLED PERSONS

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ABSTRACT - A 1982 Omega was modified and instrumented to provide objective measurement of the forces applied to the brake, accelerator and steering wheel by disabled persons as well as their reaction time. The Driver Assessment Unit augments an established driver training programme.

RÉSUMÉ - Une voiture Omega 1982 a été modifiée et dotée d'instruments pour obtenir une mesure objective des forces appliquées à la pédale de freinage, à l'accélérateur et au volant par les personnes handicapées, ainsi que de leur temps de réaction. L'Unité d'évaluation des conducteurs complète un programme reconnu de formation des automobilistes.

INTRODUCTION

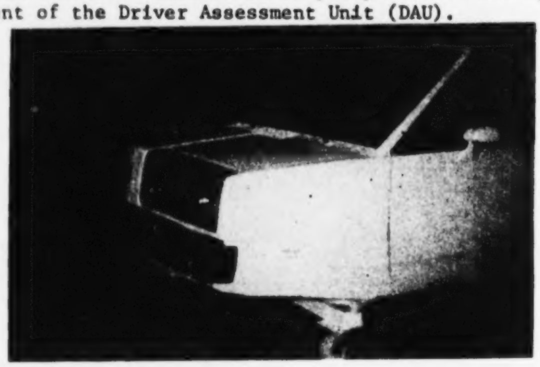
For disabled individuals driving increases the opportunities for independent living, including vocational, recreational and social pursuits. Public transportation is often inaccessible, inconvenient and/or unavailable when required. As a result, having disabled persons drive their own vehicles is recognized as the most practical solution (7).

BACKGROUND

A formal driving programme for disabled persons has been available at the Kingston General Hospital since 1978 through the Occupational Therapy Department. Assessment and training is available to persons who have suffered a severe or disabling illness or accident (quadriplegia, amputation, stroke, and so on) and are anxious to resume driving and to persons with congenital or acquired disability in childhood (cerebral palsy, head injury and so on) who have never driven. The objective is to assist potential drivers to meet the standards set by the Ontario Ministry of Transportation and Communications and thereby permit them to take their place on the road as capable and safe drivers.

The initial assessment by the occupational therapist includes evaluation of the person's physical, cognitive and perceptual functions. The individual must demonstrate evidence of good concentration, judgement and insight. A battery of functional and pencil and paper tests are available to evaluate the present of cognitive and/or perceptual deficits that might interfere with driving ability. The therapist must be confident that the individual has sufficient muscle power, range of motion and reaction time to safely operate the controls of a car before being evaluated on the road. Some potential drivers require special seating, cushions, and/or shoulder harness support. A stationary car assessment determines the optimum seating position for the driver to view his driving environment, reach the auxiliary controls on the dashboard and maintain adequate trunk support without fatigue. Appropriate adaptive driving devices such as hand controls, steering devices and so on are recommended on the basis of the initial evaluation and the occupational therapist's clinical exerience in consultation with the potential driver and the driving instructor.

Experience has shown that the clinical tests presently in use are inadequate for determining the physical capabilities for driving. Recommendation of adaptive driving equipment is also subjective and used to some extent on a trial and error basis. These concerns prompted the development of the Driver Assessment Unit (DAU).



LITERATURE REVIEW

There has been relatively little documentation of objective evaluation of driving tasks and equipment. Gurgold and Harden (1) described force and reaction requirements for driving tasks by both disabled and non-disabled drivers. Koppa et al (3) described an evaluation device using inexpensive off-the-shelf components to determine the static force capability of a disabled driver on a steering wheel and hand controls. Reger et al (6) described a Driver Evaluation/Trainer Aid for the Handicapped in which driving controls were instrumented to permit evaluation of the major driving functions simultaneously and training using variable mechanical resistance.

Simulators have been used to varying degrees to assess and train defensive driving skills, hazard perception, emergency reaction procedures and various driving control motions (4,5,7). Some workers (7) feel that simulator scores are good predictors of actual behind-the-wheel driving performance, while others (2,5) note that the simulator is confusing to some patients and a more realistic environment is preferred.

MATERIALS AND METHODS

In 1982 funds were received from National Health Research and Development Program (#6606-2233-01) and Queen's University for the design and development of a Driver Assessment Unit (DAU). A 1982 Omega was modified and instrumented to provide objective measures of the forces applied by a disabled person to the steering wheel, brake and accelerator and their reaction time. A tilt steering wheel, clutch and gear shift were installed along with hand controls and various steering devices.

The original steering system was dismantled and the hydraulic actuator was redesigned to provide variable resistance from zero to locked. The steering wheel was instrumented with a strain gauge bridge fitted to the torque transmitting shaft and with a potentiometer driven by the steering column. The transmitted signals are eventually relayed to a two channel strip chart recorder that is situated in the glove compartment providing a permanent record. The strip chart records both the steering wheel displacement and the applied torque simultaneously and an event marker indicates the time elapse during displacement of the steering wheel.

The brake master cylinder was modified and a pressure switch was installed in the system which is activated when the hydraulic fluid pressure reaches a predetermined value proportional to the brake force. A strain gauge bridge was fixed to the pushrod between the pedal and master cylinder. The amplified signal is transformed into a digital read-out located on the dashboard. The brake force can be measured using foot or hand controls.

The accelerator pedal was fitted with a return spring offering the same resistance to movement as normally found. The speedometer system was modified so that as the accelerator pedal is depressed via hand controls or foot pedal, the speedometer needle moves indicating a certain speed in kilometres per hour.

The reaction time is measured on an electronic stop watch which is activated when a manually operated foot switch causes a red hazard light to appear and is stopped when the pressure switch in the hydraulic brake system is activated.

The clutch pedal was installed and fitted with a resisting tension spring. A limit switch was installed so that when the clutch is fully depressed a green light appears on the dashboard. A standard floor mounted manual gear shift was installed and fitted with a machined gate block and a hydraulic damper to provide some resistance to shifting.

A 12 volt battery supplies the electrical power for all the auxiliary services such as headlights, horn, and so on. A power supply for the 12 volt battery charger is provided through a retractable lead located under the front bumper.

DISCUSSION

The development of an objective evaluation tool such as the Driver Assessment Unit will permit an assessment of the physical capabilities of potential disabled drivers with or without the use of hand controls and/or steering devices. The proper seating position, use of seatbelts and management of auxiliary controls can all be assessed in this realistic environment.

Three levels of steering resistance (standard, power-assist and zero-effort) can be provided. If the individual lacks strength or range of motion, the angular displacement of the steering wheel slows, the torque decreases and this change is recorded on the strip chart. The force applied to the steering wheel at different positions can be measured directly and if necessary a rehabilitation programme can be specified. The length of time that force is maintained on the brake pedal (an average red light) will be measured to determine the effect of fatigue with sustained effort. The effects of spasticity, tremor and diminished proprioception and coordination will be evaluated by measuring the reaction time from the presentation of a red hazard light while maintaining a specified speedometer reading for a specified length of time to reaching a predetermined brake force. The evaluation provided by the DAU will enable the therapist to determine the appropriate adaptive equipment required. Recommendations for training can be made with greater assurance to driving instructors and to the Ontario Ministry of Transportation and Communications regarding licensure. For the person who is advised not to drive at present, a valid objective assessment will assist him/her to set specific goals for future therapy. Although the matter of whether disabled drivers have better or worse safety records remains contradictory, a valid objective evaluation will assist in producing future safe disabled drivers.

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QUANTITATIVE ASSESSMENT OF RESIDUAL CAPABILITIES AS A METHOD OF PREDICTING DISABLED DRIVER PERFORMANCE

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ABSTRACT - An evaluation system was developed at the NIHR Louisiana Tech University Rehabilitation Engineering Center for personal licensed vehicles that gives a quantitative measure of the residual physical capabilities of a handicapped subject and predicts the subject's potential to successfully complete a driver education program. The evaluation system is described and the results of two sampled subjects that have been evaluated are discussed quantitatively.

RÉSUMÉ - Le NIHR Louisiana Tech University Rehabilitation Engineering Center a mis au point un système d'évaluation pour les véhicules personnels immatriculés qui donne une mesure quantitative des capacités physiques résiduelles chez un sujet handicapé et qui permet de prévoir la capacité du sujet à réussir un cours de conduite automobile. On décrit le système d'évaluation et on discute, du point de vue quantitatif, les résultats obtenus par deux sujets échantillonnés qui ont fait l'objet d'une évaluation.

INTRODUCTION

The high returns (in terms of finances and morale) on the investment of money into driver evaluation and training programs for the disabled has been clearly shown (Lynn et al. 1977). Based on these results, additional efforts are being expanded at all levels of government as well as private industry. Although experienced professionals involved in these programs have done commendable work in helping disabled persons to drive, they have been limited by: (1) the subjectiveness of the testing procedures popularily used (Less et al, 1978), and (2) the philosophy or attitude assumed during the evaluations of driving ability. The lack of objective and quantifiable evaluations produces wide varience in the results; thus, precluding many individuals from any possibility of driving and causing, in some cases inadequate prescription of assistive devices for those found potentially capable of driving. This unsystematic prescription of devices often results from the inappropriate philosophy assumed by many evaluators who define the extent of an individual's handicaps rather than the extent of his/her abilities as they pertain to the driving task. The purpose of the evaluation system is to provide a cost effective means for accurately and objectively quantifying the residual physical capabilities of disabled persons and to predict their potential ability to drive a personal liscensed vehicle.

METHODS AND MATERIALS

The Louisiana Tech University Rehabilitation Engineering Center's driver evaluation facilities include a Human Factors Laboratory and a Driver Simulator Laboratory. In these labs, an individual's ergonomics and cognitive abilities can be measured by means of computerized and normalized testing procedures.

After initial screening, the residual physical capabilities of the subject are tested in the Human Factors Laboratory (Fig. 1). The tests include vision, hearing, gross muscle and sensory examinations, static and dynamic strength, and reaction time assessments.

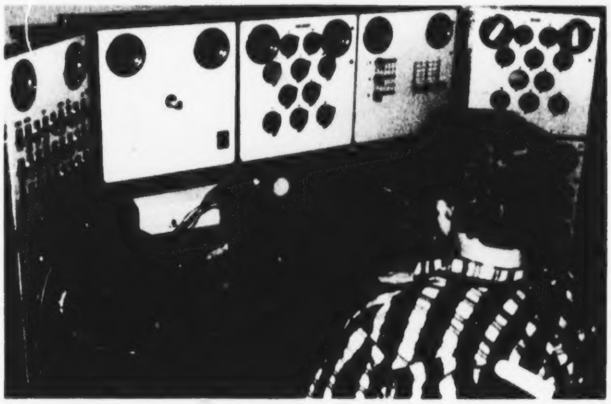

Figure 1 Human Factors Laboratory

If the subject successfully completes these tests, he/she proceeds to the Driving Simulator Laboratory (Fig. 2) for further testing. These additional tests are run on a driving simulator developed at Louisiana Tech University. This simulator utilizes a two-dimensional tracking task that provides the subject with the illusion of highway driving and requires responses closely correlated with those elicited during actual driving.

Figure 2 Driving Simulator Laboratory

Seven basic manuevers were simulated to represented a variety of driving situations. The maneuvers last 30 to 35 seconds with a maximum speed of 15 mph (24km) in manuevers 1 to 5. The manuevers are: (1) straight ahead driving, (2) right turn from stop, (3) left turn from stop, (4) right turn while slowing, (5) left turn while slowing, (6) serpentine curve (S-curve) at 10 mph, and (7) serpentine curve at 15 mph. Two criteria, the root mean square (RMS) error and the number of steering reversals, indicate the accuracy with which the subject followed the dot and the stability of the response, respectively.

RESULTS

The evaluations of two representative subjects are presented.

Subject A is a 20 year old male C-5 quadraplegic. His disability was due to a driving accident in 1978. The subject suffered a complete cervical spinal lesion, so he can only be expected to regain partial control of his upper limbs. He was first tested on the driving simulator in June of 1982 and rejected from the driver education program because of insufficient musculature and poor balance. He was reevaluated in December 1983 after undergoing 18 months of physical therapy and weight lifting to improve his strength and balance.

The results of subjects A's two evaluations and change in driving potential between evaluations on the Scott van simulator are shown in Table 1. He improved his stability of response 89% by decreasing the average number of reversals. The average decrease in RMS tracking error was 56%. Note that improvement occurred in all of the manuevers during the second trial.

	TEST#1 (6/24/82)		TEST#2 (12/1/83)					
MANUEVER	T_{RMS}*	REV**	T_{RMS}	REV	T_{RMS}	%	REV	%
1	3.51	152	1.89	17	1.67	47.6	135	88.8
2	2.96	141	1.35	15	1.67	56.4	126	89.4
3	4.05	168	1.39	11	2.66	65.7	157	93.5
4	2.85	177	1.58	24	1.27	44.6	153	86.4
5	3.08	168	1.49	22	1.59	51.6	146	86.9
6	2.87	216	1.20	19	1.67	58.2	197	91.2
7	3.49	167	1.46	22	2.03	58.2	145	85.6

*T_{RMS} = Total root mean square values **REV=reversal

Table 1 Performance of Subject A.

Subject B suffered a severe cerebral-vascular stroke in July 1981 that resulted in right lateral paresis. He was evaluated on successive days in September 1983 and found to have ample strength to perform everyday tasks, though he still suffered from right lateral paresthesis. Because of the subject's ample strength, evaluation took place on the hand control simulator. The subject was tested first on a Drive-Master push-pull hand control and then on a Wells Engberg push-twist hand control. Performance was well below normal for both tests as shown in Table 2. While the subject was strong enough to perform the driving tasks, manuevers requiring right/left coordination were difficult. Results of the driver simulation were poorest when these moves were required. It was recommended the subject undergo cognitive therapy and then be reevaluated on the driver simulator.

MANUEVER	ABLEBODIED		TEST 1		TEST 2	
	REV	T_{RMS}	REV	T_{RMS}	REV	T_{RMS}
1			189	3.80	211	1.87
2			137	1.94	109	2.42
3			144	1.97	108	2.40
4			171	2.67	133	3.05
5			138	2.68	95	2.06
6	16	.588	236	1.98	194	1.62
7	13	.692	170	1.77	159	2.17

Table 2 Performance of Subject B

CONCLUSIONS

The results of these evaluations show that a quantitative measure of driving potential can be obtained by using a driving simulator. The ability of the subject can be compared to the able bodied population and the change in ability (improvement or regression) following therapy can be quantitatively measured. The quantitative results give a guage of potential to drive not available in any previous tests. By interpreting the results and finding what manuevers gave the subject difficulty, therapy to improve skills can be recommended. Currently, data is being generated which will allow further correlations between client progress in the actual training sequences and the evaluation described.

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INFORMATION SYSTEMS AND EDUCATION/
SYSTÈME D'INFORMATION ET ÉDUCATION

EDUCATING ENGINEERING STUDENTS IN A LIFE-SPAN APPROACH TO DESIGN

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ABSTRACT - Typically engineering design students get exposed to a great deal of theory and analysis, but very little practical application. The purpose of this exercise was to introduce students to human factors and design issues from a broader, life-span perspective and to give them the opportunity to apply this knowledge to a real-life design problem.

RÉSUMÉ - En général, les étudiants en design industriel sont grandement exposés à la théorie et à l'analyse, mais ils le sont très peu aux applications pratiques. Le but de cet exercice était d'initier les étudiants aux facteurs humains et à des questions de design à partir d'une perspective plus vaste, s'étendant sur toute la durée de la vie, et de leur fournir l'occasion d'appliquer ces connaissances à un problème de design réel.

INTRODUCTION

The students targeted for this project were enrolled in an upper division engineering design class,"Product Design and Human Factors". The course had three main objectives: to learn about subjective values and aesthetics; to learn about value-related human factors (what people like), human factors in anthropometrics (the sizes of people) and ergonometrics (how people do things); and to design products under severe time constraints.

Often the projects in such classes are based on hypothetical situations, not real life. This is a problem, especially when products are being designed to address human needs. The problem is further compounded when the life span of the user/needer population is considered. Such an approach includes the elderly, people with disabilities, and any others who do not fit the standard human factors' profile. The importance of designing from a broader perspective is consistent with the generally accepted definition of human factors. The Veterans Administration Rehabilitation Research and Development (RR&D) evaluation team adheres to this definition and, accordingly, seeks to optimize the relationship between the human and technology. The Interaction Evaluation Model, developed by Engelhardt et al., is evidence of this concern.

One goal of this exercise was to provide an appropriate educational experience for the students and to increase their understanding of the needs of the elderly. Another was to investigate a new approach to providing additional feedback to manufacturers concerning their products. (The latter goal was driven by the Technology Transfer portion of the evaluation model, as applied to this project.) Product evaluation and technical development need not take place in clinical or academic isolation.

BACKGROUND

The device that the students ultimately redesigned came to the attention of K.G. Engelhardt, evaluation supervisor for the VA RR&D center, in early 1983 at the Western Gerontological Society's yearly conference. At this time she hypothesized that the existing design of the human interface might decrease end user compliance. Soon after the conference, Joan Pease of Partners in Planning conducted a formal nationwide evaluation of the Lifeline emergency alert system. Her research showed a need for redesign of the human interface. She recommended to the manufacturer that the RR&D Center be given the task of redesigning the "Personal Help Button".

While discussing another engineering design project for a class in needfinding, the Lifeline device was mentioned. It was thought to be an appropriate project for the Human Factors in engineering class at Stanford University. Subsequent arrangements were made with the manufacturer and the Human Factors'course lecturer, William Moggridge. The project was presented to the class as a real problem, with particular emphasis placed on the needs, desires and capabilities of the end users. The components of the existing system were discussed with a battery expert and some leeway was given in the use of alternate power sources. Patrick Phillipps, the Vice President of Engineering at Lifeline agreed that the alternatives suggested by the students were viable, with moderate capital investment. (While this was not an original design goal, it was accepted because of its appropriateness to the device.)

METHODOLOGY

The students presented twice during the two weeks of the project. The first presentation required two-dimensional work, design ideas illustrated by sketches and an exploded view of parts; the second required non-working prototypes. There was a good deal of interaction between the students and the development team— Patrick Phillipps of Lifeline, William Moggridge, the lecturer and Karen Holloway, project coordinator— during the whole design process. While no one project addressed every issue, the group as a whole addressed them all. Members of the interdisciplinary evaluation team at RR&D reviewed a videotape of the projects made at the final presentation. This review led to the development of criteria for further evaluation of the student designs. (See figure 1.)

DISCUSSION/CONCLUSION

The results of this exercise were exciting; the students took many different approaches to solving the problem. It was apparent that considerable thought and research went into the development of each design. (See figure 2.)

CRITERION FOR EVALUATION

Lifeline Personal Help Button

1. must be wearable at all times
2. waterproof
3. small
4. lightweight
5. aesthetically pleasing
6. easy to activate
7. feedback on power supply
8. feedback on switch activation
9. personalizable
10. safe (edges\points)
11. low cost
12. long-lived (disposable vs. replaceable)

FIGURE 1

FIGURE 2. Student presenting design to be worn about the neck.

The sequence of events leading to the redesign of the Lifeline Personal Help Button fits well into the framework of the Interactive Evaluation Model. First the device was sent, by the manufacturer, to Partners in Planning for clinical evaluation. Next, the device went to the VA RR&D for use in the student engineering project. The design proposal presented to the students was based on the information gathered by Joan Pease and the specifications set by Lifeline. Some of these specifications were challenged. Through research into new battery technology, the students discovered alternate power sources that seemed to better meet the needs and desires of the user population. The student designs were reviewed by the RR&D evaluation team and then criterion were developed to provide a framework for further evaluation. Finally, to close the loop, the device was returned to Lifeline with a videotape of the students' work, the information specific to each design and the list of criterion used to evaluate each project. (See figure 3.)

This exercise provided more that just an educational experience for the students. While the students were investigating a new approach to design, the RR&D evaluation team investigated the interaction between the students (academia), Lifeline (industry), and the VA (government) to develop a new approach to getting feedback to the manufacturers of assistive devices.

The project seems to have a future with Lifeline Systems, Inc. Lifeline may incorporate some of the student ideas into the next generation of Personal Help Buttons. It is hoped that this framework will lead to continued interaction between academia, industry and government.

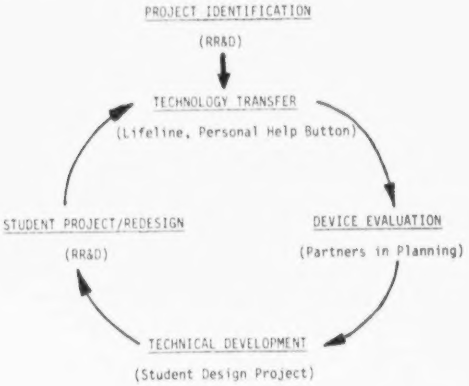

FIGURE 3

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MOTIVATION AND EMPLOYMENT OF THE DISABLED IN DEVELOPING COUNTRIES: THE NIGERIAN EXPERIENCE

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ABSTRACT - This paper discusses lack of training motivation and few employment opportunities provided for disabled persons in developing countries of the world citing studies involving some African and a few other third world nations tc highlight the low priority accorded to the training and rehabilitation of disabled persons in developing countries. The paper concludes with a plea for the intervention of technologically advanced nations.

Not many of us here are aware of the disappointments and frustrating experiences which even trained and qualified disabled youngsters encounter in developing countries inorder to find employment. Some never succeed for years, despite their qualifications, and they are forced into the street to beg in order to keep body and soul together. To give a personal example, since the past several months this vocational counsellor has struggled, but apparently in vain, to find jobs for (a) a deaf and partially sighted girl who, after her primary education, took a four-year course in sewing. (b) a crippled youngman on wheel chair who after completing a secondary course four years ago is still looking for an employment even though his disability affects only his lower limbs.

There are many cases like these all over African countries and in many underdeveloped nations. In view of this situation, who will say that a disabled person does not need motivation to train, when despite his sufferings to get an education and to train for a job, he is faced with discrimination, unemployment or under-employment. In fact, the situation was so bad a short while ago in Nigeria that the Executive Secretary of the Federal Nigerian Society for the Blind exclaimed:

> "There are a few organisations, mostly voluntary who try to rescue our handicapped brothers and sisters from the disgrace of permanent dependence by training them for job performance and for placement, but their joys are shortlived when it is found that handicapped people who have been trained at great cost in money, time and by dint of obstinate human patience and endurancnce can only waste away because there is no opportunity to use their training in employment. Even when there are many avenues of use, the handicapped and those who help them to get jobs find themselves up against an insurmountable mountain of ignorance and prejudice from employers"

About the same time too, a lady Principal of the first school for the deaf in Nigeria cried out in these words: "The placement of deaf children after completion of their training is creating a very big problem. Most firms and government establishments have been very hesitant to employ "tonguetied" elements that have been sent to them for employment. It is extremely difficult to find jobs for girls. This is very discouraging to both the teachers and the poor handicapped children. The boys are trained together with normal children for three years and pass the same trade test. These children are capable of doing the work for which they have been trained, but the employing agencies still feel they cannot be useful citizens. It is therefore important to stress that unless the society in which deaf children exist is prepared to tolerate and appreciate their little achievement, the objective of educating them would be lost".

Although these statements were made a few years ago, it would be a mistake for anyone to think that the situation has very much improved since that time. In a survey of employment opportunities for disabled people in Nigeria by Mba (1982), the following findings were made:

1. Of 120 employers who completed questionnaires, 69% would give employment to deaf persons, 32% to blind jobseekers, 48% to moderately mentally retarded persons, 36% to physically handicapped persons, 19% to the emotionally disturbed and 16% to the multiply-handicapped.
2. Approximately 51% of those surveyed

were prepared to give jobs to the disabled persons at the time of the survey.

3. About 26% of the prospective employers would insist on education, vocational training and good behaviour as criteria for employing disabled persons, 35% of them would require only training and good behaviour of the prospective employees, while only 15% indicated they would want education alone as criteria. Surprisingly, only one would-be employer stated that his only criterion for giving a job to a disabled person would be good appearance.
4 Sixty-seven and half percent of the employers would want some legislative measures that would compel employers to reserve a certain percentage of their job openings for disabled persons; 30%, however, would not support the idea.
5 Some of the resons given by those who would not like to employ disabled persons include: (a) handicapped people would not be productive in their particular employment (b) Some disabled people are bad. (c) employment of disabled persons is against the establishment's policy (d) the company has no knowledge of dealing with handicapped persons (e) the company has no vacancy etc. On the other hand, those employers who signified a willingness to employ disabled individuals said they would do so on humanity grounds, or "that they want the handicapped to be independent and self-supporting, or the disabled persons have a right to live". Unfortunately, those who expressed negative attitudes by far cutnumbered those who were positive.

In a more recent study of special education programmes in selected 19 developing countries, including: Gambia, Ghana, Kenya, Lesotho, Liberia, Libya, Tanzania, Uganda, Upper Volta, Zimbabwe, Niger, Senegal, Ecuador, Korea, Thailand and Taiwan, Mba (1983) noted that more than 80% of the countries surveyed listed as their major difficulties in providing (or expanding) services for the handicapped: (1) Low priority accorded to special education by their state, and consequent lack of funds for facilities, and equipment. (2) Lack of trained staff and facilities for training them (3) Few employment opportunities for the handicapped.

In many developing countries, education in all its aspects has become the main industry of the nation. This is as it should be in view of the fact that every where people have come to ascribe their lack of technological "know how", low par capita income, low level of industrialization and even high incidence of diseases and alarming death rate, to low-level of education. But despite the stampede to provide education, ostensibly for "all" in most of these third-world countries, education of handicapped children is still in the most rudimentary stage, woefully inadequate, hapzardly planned and poorly funded. The following random data from Mba's study cannot but give cause for concern among humanitarians and people of goodwill everywhere:

	Estimated or Actual No. of School-age Children	Percentage of Handicapped in School	Estimated or Actual No. of Handicapped in Country	Percentage of Handicapped in School
Ghana	409080	0.41%	420000	0.40%
Liberia	920000	0.01%	43382	0.25%
Nigeria	8,000000	0.40%	1,000000	0.40%
Tanzania	2,045650	0.09%	572000	0.32%
Zimbabwe	2,800000	0.11%	70000	4.29%••
Ecuador	1,631000	0.13%	260000	0.81%
Korea	11,400000	0.09%	442600	22.23%••
Taiwan	3,284121	0.49%	15966	4.90%••
Thailand	4,800000	0.06%	460000	0.65%

•• It is most likely that the actual number of handicapped children in these countries far exceeds the number given by them.

Taken together, employment of disabled persons in many developing countries is not regarded as their right, but as a rare privilege for which they should be eternally grateful. Fortunately, many nations have become aware of the need and have been up and doing. In Nigeria for instance, the 1977 National Policy on Education which is widely regarded as the most significant document in the annals of education of the handicapped in Nigeria, states:

a) "The education of handicapped and gifted children will be free at all levels, up to the university level where possible."
b) "Vocational schools will be made to reserve places for further education of handicapped children and adults... Government will provide suitable employment opportunities for handicapped workers . . . ."

Significantly, since 1977 when this declaration was made, the number of schools for handicapped children in the country has increased by leaps and bounds. Be all this as it may, it must be pointed out that the recent spurts of world wide activities stem from U.N. and other non-governmental organizations. These voluntary agencies need encourage-ment from all of us. Can we help the disabled in developing countries?

TECHNOLOGY AND REHABILITATION - INDIAN SCENE

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ABSTRACT - The socio-economical situation prevalent in the developing and under developed nations of the world which are largely populated provides a formidable challenge to rehabilitate persons who are handicapped by birth or by accidents. Various aspects are analysed with reference to India which have equal relevance to other developing and under developed nations.

RÉSUMÉ - La situation socio-économique qui prévaut dans les pays en voie de développement et sous-développés à forte population, constitue un obstacle imposant à la réhabilitation des personnes qui sont handicapées de naissance ou à la suite d'un accident. Divers aspects de la question, qui sont également applicables à d'autres pays en voie de développement et sous-développés, sont analysés dans le cadre de la situation en Inde.

India is a very unique and diverse nation of over 700 million people belonging to various faiths and religions speaking a wide range of languages. Majority of the people are poor and the affluence may be around 20 per cent. About 80 per cent live in rural and semi-rural areas, so the rehabilitation of the handicapped due to birth deformities or due to accidents even if it forms a minor fraction of the total population is a most formidable and challenging task. The social situation warrants simple, cheap, rugged devices, gadgets and appliances for being used in urban as well as rural settings under ranging weather conditions by handicapped persons of varying levels of intellect. The problems and the solutions have realistic and practical relevance to all similarly placed developing and under-developed nations of the world. The resources of the government and majority of people are limited and an optimum and planned utilisation has to be ensured. Despite these drawbacks, missionary institutions and voluntary agencies are doing their best to provide the poor and the needy with gadgets and devices at low costs or free of cost. Growing rate of population, higher longivity, larger rate of birth deformities and higher number of accidents aggravate the problems already faced in rehabilitating the handicapped.

Considering the gigantic magnitude of the task, the rehabilitation programmes have to be planned and executed. Broadly, the handicapped may be classified as (a) Blind and near blind (b) Speech and Hearing (c) Physically handicapped (d) Mentally handicapped (e) Cerebral Palsied (f) Infantile Polio (g) Leprosy. An integrated teamwork approach is absolutely essential for the optimum utilisation of the financial resources and also utilise the technological devices, gadgets and appliances available. There appears to be unlimited scope for developing new innovations for providing relief for the handicapped. The integrated teams should comprise of (a) medical specialist (b) Therapist (c) Social worker (d) Clinical psychologist and (e) Neuropsychiatrist. Many orthopaedic surgeons in the country have appreciated the need to associate psychiatrists and clinical psychologists in regard to the rehabilitation of amputees. Various systems of medicine are currently in vogue in the country, namely: Ayurvedic, Homeopathic, unani, etc. These have provided relief in many cases when the conditions were not responsive to modern medical techniques. The Oesteopaths have played an important role in case of fractures by their bone setting techniques. The famous "Jaipur Foot" is yet another example of a simple but an invaluable device for the amputees. Many polio victims have been treated by massaging using some oil. All these are of immense relief value for the masses in highly populated poor developing and under-developed nations at very reasonable costs. So it appears inevitable that an integrated approach utilising all available techniques, devices and gadgets provides the best answer for rehabilitation of various types of handicapped. Other techniques like naturopathy, electroaccupuncture, magnetotherapy are also being used to treat arthritis and other physical ailments. Scientific evaluation on a planned basis is now being envisaged on some of these techniques which have provided relief to thousands of poor over the years in the country.

It is worthwhile analysing at this stage certain data about the handicapped in the world. Over 450 million are disabled (ten per cent) and 75 per cent do not get trained help. Nearly 175 million are children under 15, 80 per cent of the disabled are from the developing and under-developed nations. Malnutrition is most certainly the major cause of disability accounting for over 100 million disabled. Nearly 0.25 million lose eyesight due to Vitamin A deficiency. Communicable diseases disable nearly 150 million. Mentally retarded number about 50 million. Congenital disables claim about 100 million. Accidents kill nearly 0.25 million and disable nearly 3 million annually. At work nearly 0.1 million die and 150 million are disabled. Accidents at home disable nearly 3 million. Speech and hearing disable nearly 80 million. An estimated 50 million are blind. Trachoma affects 400 to 500 million of whom 4 to 5 million are totally blind. Severe visually impaired total about 20 million. Cerebral palsy claims nearly 15 million. Leprosy and Epilepsy disable about 25 million each and in India, malnutrition is the major cause of disability nearly 60 million children suffer. 80 to 90 per cent do not get key vitamins and minerals. 75 per cent do not receive enough colories and 50 per cent do not get enough proteins. Every month nearly 0.1 million children die and about 15,000 go blind. About 25 million are handicapped due to various types, out of these nearly 10 million are blind, a million deaf, a million orthopaedically handicapped. Mentally disabled total nearly 15 million and spastics number nearly 2 million. The figures indicate the gigantic task of rehabilitating the handicapped.

Rehabilitation is an integrated and multidisciplinary task. No individual working in isolation can solve the problem. The engineer, doctor, social worker, therapist, psychologist form the team. The rehabilitation engineer is the vital and integral link. Most unfortunately, this aspect has not been appreciated in most of the developing and under-developed nations of the world. In fact, many are not aware of the terms rehabilitation engineering and rehabilitation engineer, but the fact remains that the engineer is the person who ultimately devises and fabricates the devices, gadgets and appliances required by the handicapped. This ofcourse is done in close association with the team from the fields of medicine and psychology. Engineering skill of very high calibre is needed particularly from the fields of mechanical and electromechanical for the fabrication of appliances. The engineer has to coordinate all these activities. His role is very vital in planning techniques and devices to suit the handicapped. In the present day, planning and organising short term courses and workshops as part of continued education programme has become absolutely essential to keep the concerned medical, paramedical and other members of the group informed about improvements in techniques, appliances and gadgets.

Technology in the form of innovation of various new techniques, devices, gadgets and appliances has played a very vital role in the rehabilitation of various types of handicapped even in developing and under-developed nations of the world. May be slight difference in regard to design may be necessary for appliances to be used in rustic rural settings compared to urban ones. The areas used in rural areas may be more rugged to suit the environment there. In the field of speech and hearing handicapped, individual and group speech therapy devices and hearing aids have played a useful role. Similarly a number of devices have helped in the rehabilitation of blind and visually impaired, orthotic and prosthotic devices and their impact in rehabilitation is too well known. Higher longivity and higher rate of growth of population further aggravate the herculean task of rehabilitation. But human and social considerations make it mandatory to meet the challenge and provide a chance for the handicapped to lead a near normal life.

LA FORMATION CONTINUE DES PRATICIENS DU CENTRE FRANÇOIS-CHARON PAR LE RECOURS À UN PROGRAMME D'ÉVALUATION DES INTERVENANTS PAR LES PAIRS[1]

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RÉSUMÉ - Au Centre François-Charon nous avons fait l'expérience d'un nouveau modèle original de formation continue par les pairs qui s'inspire de la méthode Delphi. Les participants ont proposé eux-mêmes un paradigme d'interventions de qualité et en ont examiné la pertinence dans leur pratique quotidienne.

ABSTRACT - At Centre François-Charon we have developed a new model of In Service training inspired by the Delphi method. The participants present examples of real life problems to which solutions are proposed, then through discussion and role playing the validity of the solution is tested.

I. INTRODUCTION

Le projet de formation continue au Centre-François Charon (1) a fait suite à une recommandation du D.S.C. du Centre Hospitalier de l'Université Laval, qui travaillait depuis 1976 à la réalisation d'un programme pilote de réadaptation fonctionnelle et de réinsertion sociale dans l'Est du Québec. Il s'inscrivait également dans l'esprit des changements survenus dans le domaine de la réadaptation ces dernières années, conséquemment à la nouvelle perspective dite de réadaptation globale. La formation visait à faciliter aux intervenants le passage d'un modèle médical à un modèle global. Le projet s'adressait à tous les intervenants volontaires de façon à créer chez eux des habitudes de travail en équipe multidisciplinaire.

Pour réaliser nos objectifs, nous avons élaboré un modèle andragogique à partir de quatre sources principales: la technique connue sous le nom de *On site saturation technique* proposé par l'équipe de T. Hickey (2); la méthode Delphi adaptée à des objectifs de formation (3,4); la formation par les pairs (4) et le Théâtre-forum (5). Dans ce modèle, la formation se déroule dans le milieu de travail, les intervenants contribuent à générer la théorie qu'ils ont à mettre en pratique et ils discutent entre eux des modalités d'application de la théorie, en particulier grâce à des mises en situation comme le Théâtre-forum ou les jeux de rôle.

II. LE CONSENSUS AUTOUR DES CRITERES D'INTERVENTION DE QUALITE PAR LA METHODE DELPHI

Au tout début, le projet fut présenté aux intervenants du Centre François-Charon et, suite à cette activité, 68 praticiens ont manifesté le désir de s'inscrire au programme de formation continue. Ils provenaient des quatre programmes du C.F.C. et représentaient toutes les catégories d'intervenants en réadaptation.

LA METHODE DU DELPHI

La méthode Delphi a constitué un élément essentiel du nouveau modèle andragogique que nous voulions expérimenter. Elle fut utilisée à différentes fins depuis une trentaine d'années (prédiction, planification,etc) (3) mais c'était une des premières fois qu'elle était utilisée dans un contexte de formation. A notre connaissance, seul le projet de l'Ecole de pharmacie de l'Université Laval visant la prescription médicale et dirigé par le docteur Jacques Tremblay (4) a utilisé la méthode dans un contexte similaire.

Le Delphi est essentiellement une méthode de communication visant à obtenir un consensus parmi un certain nombre d'experts interrogés concernant des questions pour lesquelles il n'existe pas de théories exactes. Dans ces domaines où il existe une multiplicité de points de vue (pluralisme théorique), nous postulions que l'opinion consensuelle des experts pouvait tenir lieu de théorie exacte. Dans tous les domaines de la réadaptation où il existait certaines controverses, il était possible d'utiliser la méthode Delphi. Ces domaines allaient des attitudes générales face à la réadaptation jusqu'à certaines interventions spécifiques aux différentes conditions, sans entrer cependant dans les questions de technique propres à chacune des catégories de professionnels.

Le processus de la consultation Delphi peut être divisé en cinq phases distinctes:

1. Il y eut d'abord une mise au point des critères. Cette phase a débuté par une recherche bibliographique en réadaptation, suivie d'une consultation de la littérature de façon à faire ressortir des critères d'intervention;

2. A partir d'un ensemble de critères nous avons élaboré les Delphi couvrant les différents aspects de la réadaptation;

3. Une fois élaborés dans leur version préfinale, les Delphi furent soumis à des spécialistes de la réadaptation, à des praticiens de même qu'à des professeurs;

4. En tenant compte des suggestions des spécialistes, nous avons procédé à l'élaboration des versions finales des Delphi I. Ces versions furent ensuite présentées aux intervenants.

5. Les résultats des Delphi furent compilés en notant les modifications suggérées par les intervenants. Ensuite, nous avons élaboré une seconde version des Delphi en tenant compte de ces modifications. Ces Delphi II furent donc constitués d'un ensemble de critères originaux modifiés et d'un ensemble de critères non modifiés.

Puisqu'il y a eu de très forts pourcentages d'accord dans les réponses aux Delphi II, il ne fut pas nécessaire de procéder à une troisième phase.

III. LA CONFRONTATION DES CRITERES AVEC LA REALITE QUOTIDIENNE

Après avoir défini par consensus le cadre théorique devant déterminer les interventions ou du moins l'esprit des interventions concrètes, les intervenants furent amenés à confronter leur pratique quotidienne à ces critères théoriques idéaux. Le but de ces séances d'analyse de la pratique consistait à soumettre les gestes thérapeutiques quotidiens à une remise en question constructive. Les analyses de la pratique se sont déroulées en présence des pairs, c'est-à-dire des membres de l'équipe multidisciplinaire. Ce sont ces derniers qui ont procédé à l'évaluation des interventions. Ils constituaient en définitive les formateurs véritables dans un processus de formation par les pairs, les membres de l'équipe de recherche n'étant présents qu'à titre d'animateurs.

Au cours des analyses de la pratique, les intervenants ont identifié des contraintes les empêchant de réaliser dans leur travail quotidien les normes idéales élaborées dans le Delphi. Egalement ils ont proposé proposé certaines solutions pour palier à ces difficultés.

IV. EVALUATION DES EFFETS DU PROGRAMME SUR LA QUALITE DES INTERVENTIONS

Pour évaluer le projet nous avons utilisé deux moyens: le dossier des bénéficiaires et un questionnaire selon le protocole avant et après.

Si on devait se fier uniquement à l'analyse des dossiers, on devrait admettre que les changements furent minimes. Toutefois, il faut être conscient des limites inhérentes à ce mode d'évaluation. Le dossier ne constitue pas le portrait véritable des intervenants, car ils n'inscrivent au dossier qu'une infime partie de ce qu'ils font réellement. Comme le dossier ne circule pas avec les bénéficiaires, les intervenants n'inscrivent au dossier que ce qui leur paraît absolument nécessaire.

Les questionnaires et les entrevues nous ont fourni des informations plus intéressantes. Ces instruments nous ont permis de constater que les personnes handicapées étaient perçues plus positivement à la fin du projet, que le travail en équipe multidisciplinaire a été renforcé et que les conférences de cas sont devenues plus profitables aux yeux des intervenants.

[1] Ce projet fut dirigé par Gilles Bibeau et Lucie Turgeon-Rheault de l'Ecole des sciences infirmières de l'Université Laval. Ont également participé comme chercheurs: Marthe Lavergne et Normand Leavy de l'Ecole des sciences infirmières de Laval, Charlene Poulin de l'Ecole de réadaptation de Laval, Nicole Brunet-Perreault et Ginette Deschênes du Centre François-Charon. Il fut subventionné en partie par le ministère des Affaires sociales du Québec et surtout par le ministère de l'Education du Québec sous le volet "Fonds de développement pédagogique - Service à la collectivité."

Une version plus complète de ce texte fut publié dans la revue Administration hospitalière et sociale Vol. 29 n^{o} 1: 31-36; de même que dans les procédures de la conférence Systed 1983, Charles Tilguin (ed.). (à paraître)

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INTERACTIVE VIDEO EDUCATION SYSTEM FOR REHABILITATION

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ABSTRACT - A prototype system has been designed to enable physically disabled individuals to independently access video educational material. It is automatically activated by the approach of a user, and is voice operated. The system is undergoing clinical evaluation and concurrent development.

RÉSUMÉ - Un système a été développé qui offre aux handicapés physiques le moyen d'accéder des segments enregistrés sur une cassette video. Le système s'initialise à l'arrivée de l'utilisateur et est commandé par la voix. L'évaluation en clinique vient de commencer et le développement technique continue.

Need

In order to facilitate a return to active and fulfilling lives, spinal cord injured patients, and those associated with their care, need to learn a wealth of information. Rehabilitation is largely an educational process where routine issues in life are reexamined and new approaches learned [3]. Information about activities of daily living, vocational opportunities, and recreation are just a few of the important concerns of an effective rehabilitation program. This information should be available to disabled users so that they can independently access it when they need it or are ready to learn it. Thus, people with physical disabilities need an educational tool to assist them in their rehabilitation.

Problem

This need poses the problem of how to give physically disabled individuals access to a large resource of rehabilitative information. Presently, this is a labor intensive process that tends to place the patient in a position of dependence on the health care staff. Ideally, a rehabilitation program should be flexible enough to accommodate the variety of needs and learning rates among the patients. Such flexibility could also allow individuals to govern their own pace through rehabilitation, further encouraging their personal initiative and independence.

For the physically disabled, however, their ability to interact with conventional educational aids may be impaired. For example, videotape is a convenient and effective medium for instructional rehabilitation [2]. However, many disabled patients are unable to independently operate video playback equipment. This constraint indicates the need for an interface which brings the material within their range of perceptual and motor abilities. This interface must be compatible with a variety of users who have a wide range of capabilities. The user population includes high level quadriplegics, who have no use of their hands but normal head and vocal control. Able-bodied users, such as family members and health care staff, should also be able to interact naturally with this system.

Approach

Our objective has been to provide the disabled community with 24-hour independent access to video information. This involved consolidating relevant video educational material into one source and enabling all users to interact with it. We selected a total of 2 hours of video programs that were representative of currently available video material on general issues of spinal cord injury rehabilitation. They included an overview of life with spinal cord injury, instruction on activities of daily living, and information about vocational opportunities.

To make the system accessible to persons with high level spinal cord injuries, we designed it to be automatically turned on by the presence of a user. We also chose to use voice input, since it is an interface that can be operated with equal ease by disabled and able-bodied users. Since the system would be developmental in nature, modifying, adding, and experimenting with different features along the way, we designed it to be functionally flexible and easily reprogrammable. This prototype was assembled into a self-contained package that can be readily transported to different sites for demonstration and clinical evaluation. We also wanted to be able to monitor the performance of the system while it is being clinically evaluated, so the ability to automatically collect data pertaining to its own use was incorporated.

Solution

A completed prototype of the system is shown in use below. The accompanying functional block diagram helps give an overview of how it operates. An infrared proximity sensor detects the presence of a user and automatically powers up the system. Computer graphics are used to present menus which list video program topics paired with keywords. Selections are entered through the voice recognition unit by saying the keyword paired with the chosen topic. A computer controlled videotape machine locates the selected video segment and plays it for viewing. The system senses when the user leaves and automatically turns itself off. In this manner, users can independently initiate learning sessions and interactively control the content of the material viewed.

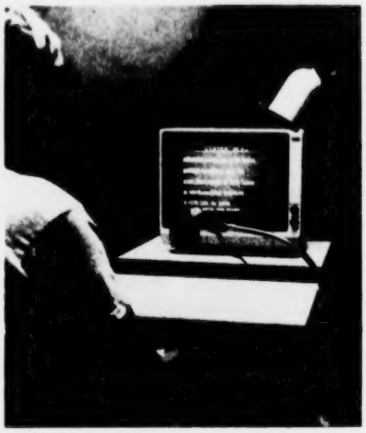

Figure 1: System in use

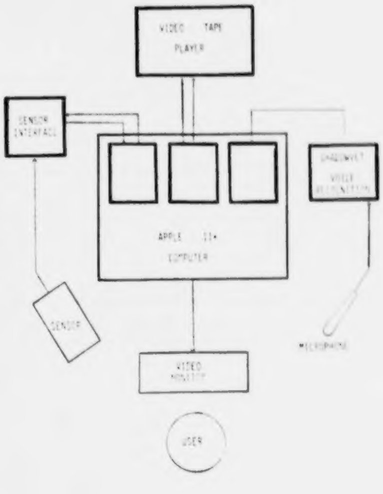

Figure 2: Block diagram of system

Users enter their input into the system through a Shadow/VET voice recognition unit. Although the Shadow/VET is intended to be a speaker dependent unit, it approaches speaker independent recognition in this application. This was accomplished by selectively choosing a small set of words which sound distinct to the Shadow/VET. The vocabulary template was trained by averaging 3 different voices (2 male, 1 female) into a composite template. In this way, the unit's voice recognition is not specific to one voice but applies to a range of voices. If a particular user's voice is not recognized, the system automatically retrains the Shadow/VET to recognize that voice.

An instrumental feature of the system is its ability to store data monitoring its own use. For each learning session, the computer records the date and time that the system is activated, elapsed time spent with the system, sequence of video programs viewed, and performance characteristics of the voice recognition unit. This information provides a quantitative measure of how the system is being used and how it is performing.

The components of the system are integrated together largely through the computer software. This allows a high degree of flexibility in experimenting with and modifying the functional features of the system. This flexibility allows the system to grow with technical advances and be responsive to changes suggested by users.

Future Work

We are currently in the process of clinically evaluating the system in health care settings. During these evaluations, the system is used by patients, family, and staff in a spinal cord injury center. Through the data automatically collected by the system, we can monitor the system's use and performance. Questionnaires are also administered to investigate users' perceptions, reactions, and feedback on the system. This information will guide the ongoing research, development, and evaluation of the system under the Interactive Evaluation Model [1].

We would like to add more user interfaces, such as joystick or touch screen, in addition to voice input. This variety of interfaces would allow users to choose the most efficient mode of input for them. It would also allow us to compare and evaluate these different interfaces. We also hope to find or produce new interactive video programs which would be relevant to the educational needs of the users. Information and training techniques pertaining to health care staff members should also be included. We plan to continue to interactively develop and evaluate this system in order to design it to best serve the needs of its users.

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CLINICAL AFFILIATION PROGRAM IN REHABILITATION ENGINEERING SERVICE FOR COMMUNITY COLLEGE STUDENTS

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ABSTRACT - Helen Hayes Hospital has set up a Rehabilitation Engineering technician training program for Community College students. These students serve in the hospital's team oriented Rehabilitation Engineering clinic which solves problems requiring therapeutic tools and assistive devices.

RÉSUMÉ - L'Hôpital Helen Hayes a mis sur pied un programme de formation de techniciens en génie de la rééducation pour les étudiants du Collège communautaire. Ces étudiants participent au travail d'équipe du service de rééducation de l'hôpital qui cherche à résoudre des problèmes nécessitant des outils thérapeutiques et des appareils d'assistance.

Introduction

Helen Hayes Hospital was the first totally independent rehabilitation hospital and is the second oldest state supported hospital for the treatment of physically disabled persons in the U.S.A. The State of New York established the hospital in 1900. Today, the hospital serves as a comprehensive center of patient care, education and research devoted to rehabilitation. One of the Centers involved in research is the Orthopaedic Engineering and Research Center (OERC) which brings the combined talents of the medical and engineering professions to bear on musculoskeletal problems in rehabilitation.

In response to the needs of the hospital's clinical staff, the OERC has organized a rehabilitation engineering clinic with representation from every appropriate discipline. The OERC utilizes this clinic to train electronic technology students from Rockland Community College (Suffern, NY) in Rehabilitation Engineering.

Operation

The clinic has the objective of providing custom therapeutic tools and assistive devices when no commercial alternatives exist. In no instance will the clinic provide a device readily available on the commercial market.

The clinic employs a team approach in attacking one problem each month. Once the team and client have identified the problem, they develop a solution concept which embodies their past experiences in rehabilitation. At this point, part of the team formulates a number of possible designs from the concept. The team in communication with the client decides on the most appropriate design which the students then build. This prototype must meet electrical and mechanical safety requirements to the satisfaction of an independent committee and established codes.

Before a client can use the prototype, he must receive instruction in its operation. The prototype is tested to determine if it is effective in meeting the client's needs. At this point, if modifications are necessary, the team makes the proper design changes before the students build a final device. This device receives a follow-up evaluation by the team which determines how well it meets the initial requirements. This evaluation examines: 1) performance, 2) ease of operation, 3) utilization, and 4) maintenance.

In addition to the benefits gained by the clients, this program has heightened the hospital staff and student's awareness of how technology can help the rehabilitation process. Beyond this, the students have received valuable training in how their academic and practical skills can be applied to real problems.

Detailed Project Example

Problem Statement: A 3 year old girl with equinus gait due to cerebral palsy needed rewarding feedback during gait training. The client's physical therapist requested that the clinic develop a feedback device to enhance the client's treatment. The clinic decided to consider the problem because of the possible benefits for the client and others with similar needs.

Concept: The team chose children's stories set to music as the feedback medium because the child would respond more enthusiastically to a story than to a light or a buzzer. Having made this choice, the team made a list of design specifications which the feedback device had to meet:

1) portable enough that a child could walk with the device comfortably.
2) prevent the child from hearing the story if she failed to make heel contact.
3) prevent the child from resting on the heel switch instead of walking.
4) provide negative feedback to the child by having her miss part of the story if she failed to make heel contact repetitively. (The mechanism would continue to run on silently.)

Design: These specifications led to the design of a prototype which controlled the flow of audio signals from a portable cassette player to the earphones through the output jack. The prototype allowed the audio signal to flow as long as the child's heel intermittently made contact with the floor. Figure 1 shows the main components of the prototype. This prototype received its input from a footswitch on the client's heel. A contact of the heel with the floor sent one trigger pulse to the circuit. The heel had to come off the floor and remake contact before another trigger pulse could be sent. When the circuit received this pulse, it started allowing the audio signal to flow from the cassette player to the earphones. The circuit would interrupt the signal after an adjustable amount of time if the circuit received no further input pulses from the heel switch. Note that the circuit had no effect on the cassette drive mechanism. It would only affect the equipment's output therefore introducing a negative feedback to the client by means of missing part of the story and/or songs as time goes on.

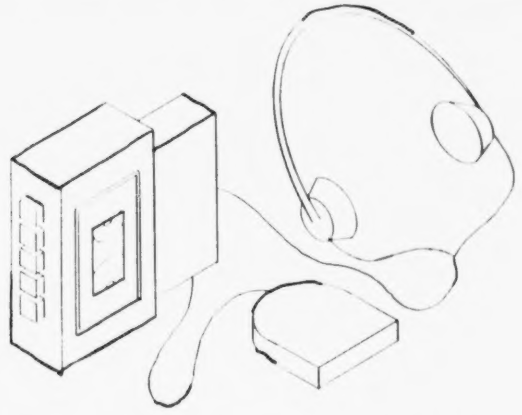

Figure 1. Main Components of the Prototype

Construction: The prototype was constructed using integrated circuitry and printed circuit board (PCB) technologies. The circuitry was AC coupled to the footswitch so that only intermittent contact between the heel and the floor would trigger the timing circuit leaving the client no other choice but to continue walking instead of resting on the switch. A CMOS monostable integrated circuit controlled the flow of the audio signals from the cassette player to the earphones and an externally controlled RC network allowed the therapist to adjust the time in which the client can retrigger the monostable. The output of the monstable controlled a double pole relay which switched both left and right stereo channels on and off. A PCB supported and electrically connected all of the circuit components. This resulted in a solid and reliable small package which could mount onto the side of the portable cassette player.

Modification: The team evaluated the prototype's performance and found that it failed to keep the child's interest. The child became more interested in using the device when someone else wore the earphones and walked with her. This phenomenon dictated a redesign of the prototype to control a record player and speaker centrally located in the room. This latter arrangement allowed the client to receive more attention than when she controlled the "closed" system.

The final device worked in the same manner as the prototype except that it used a radio transmitter and receiver instead of a wire to send the heel contact signal to the timing circuit. Therefore, the client would carry only a footswitch and small transmitter. The timing circuit was coupled to a radio receiver which would pick up the heel contact signal. Now, the timing circuit controlled the audio signals between a record player and speakers. This arrangement allowed the child to walk about freely while controlling the record player.

Benefits: This project resulted in the lessening of the client's equinus gait during treatment activities. The feedback device allowed training to progress at a faster rate. Notably, the client's stability increased; this may prevent the client from falling while running if the corrected gait carries over.

Results

To date, the clinic has developed the following devices to facilitate the treatment and/or evaluation of the hospital's clients.

1) Biofeedback device for gait training
2) Durable augmentative communication device for sheltered workshop setting.
3) Reaction time monitor for neurological assessment
4) Enhanced spirometer for pulmonary capacity training
5) Adapted switch for wheelchair control
6) EMG video game interface for prosthetic control training

Acknowledgements

Thanks to Professor Morton Leifer and Rockland Community College for their continued support of this project. Helen Hayes Hospital is operated by the New York State Department of Health.

THE ITALIAN COMPUTERIZED DATA BANK ON TECHNICAL AIDS WITH MULTILINGUAL ACCESS

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ABSTRACT - Information on technical aids plays an important role in quality improvement of Service Supply to the elderly and the disabled. The paper reviews the italian computerized data bank on technical aids, whose multilingual access feature can permit information exchange throughout the european countries.

RÉSUMÉ - L'information sur les aides techniques joue un rôle important à l'amélioration des services sociaux et sanitaires aux personnes âgées et handicapées. La communication illustre la banque des données italiennes des aides sur ordinateur électronique avec accès multilangues qui permet une échange d'informations avec des autres pays européens.

The Evaluation and Information Centre on Technical Aids (S.I.V.A.) in Milan.

In each Country information on the available Technical Aids and their features is the essential means for transfer of Technology to the Disabled and for quality improvement of Rehab Services.

At present the only Italian centre carrying out this activity is the SIVA (Servizio Informazioni e Valutazione Ausili) in Milan, run by the Fondazione Pro Juventute Don Carlo Gnocchi in conjunction with the Bioengineering Centre, and officially opened on November 29, 1982.

SIVA's tasks fall under the headings of the following activities:

1) Gathering of information on the technical aids available on the Italian Market and evaluation of their features;
2) Updating the contents of the computerized data bank on Technical Aids;
3) Making the data bank available on line through the telephone system and the DIANE EURONET network.
4) An Advice Centre, equipped with a permanent exhibition of technical aids.

SIVA is designed to be the central node of a network of user-directed Advice Centres scattered throughout Italy and directed towards the Disabled, to their relatives and friends , to Health Care Professionals and to Architects.

The European cooperation projects

Starting in 1979 the European Economic Community (EEC) undertook a survey of the information facilities regarding technical aids in the 10 member countries (Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, United Kingdom), taking into account the initiatives already in progress in the countries taking part in the Nordic Council for Disability (Denmark, Finland, Norway, Sweden).

This work permitted the planning of a future European information exchange network (HANDYNET) including information on technical aids (HANDYTEC). Handytec can be divided into 4 components:

- HANDYSEARCH, concerned with research projects;
- HANDYAIDS, an inventory of technical aids;
- HANDYWHO, which is concerned with professionals Centres and other groups involved;
- HANDYPAT, an inventory of patents.

Project HANDYVOC will estabilish the multilingual thesaurus and classification in the 10 languages of the Community and of the Nordic Countries.
The above projects will bring several advantages, among which is the possibility of carrying out the coordination of functional and technical evaluation.

Guidelines of SIVA's information system.

Taking into account the needs of the actual and potential italian users and the background of the personnel who generally act as interface between the disabled and information (health care and social service professionals), the data bank is accessible through an interactive software designed to allow the search according to the functional and environmental problems of the disabled person for whom the aid is requested. Performing data searchs is very simple and does not require previous experience in informatics.

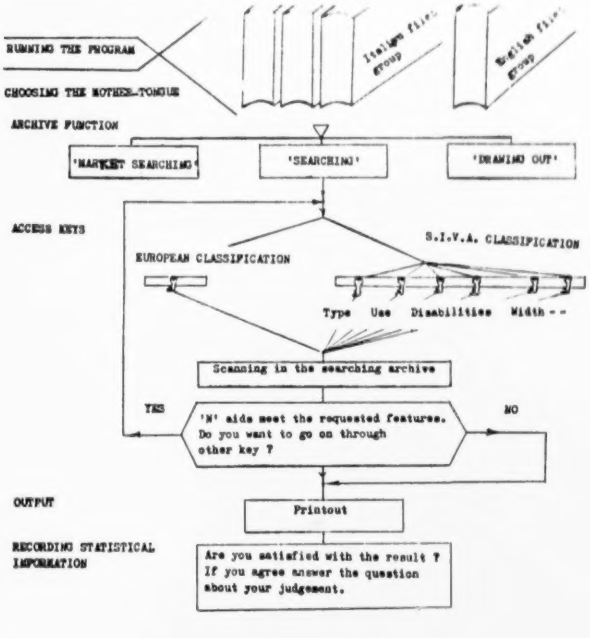
On the ground of the EEC initiatives in which SIVA is actively involved, data are stored according both to SIVA's own code systems and to the Nordic Classification, which has been chosen by EEC as the framework for the HANDYVOC European classification. A software interface between the types of aid (which constitute one of the main entries) and the Nordic Classification items has been designed.

Searchs can be performed choosing the interactive dialogues in any mother-tongue without the need to translate the description of each aid. This facility will allow access to information on technical aids on the Italian market from centres in other countries. At the end of each search the user can allow or forbid automatic registration of the transactions and of his opinion about its success. This constitutes a feedback of the system's effectiveness.

Structure of the Data Bank

SIVA's package includes:

- The main data file (composed of fixed-length records whose contents include about 50 items regarding the type, the brand name, the use, the disabilities which the aid meets, technical data, market data, Comment and evaluation), with the relevant index files;
- The bibliographic references file, including manufacturers and suppliers;
- Several groups of auxiliary files (one group for each chosen mother-tongue) containing messages, menues and decoding of codified items;
- A "history" file for registration of the transactions, allowing the processing of statistics about the actual use of the data bank;
- Data Retrieval program (AUSILI);
- Programs for updating the main file and for management of auxiliary files (for SIVA use only).


RUNNING THE PROGRAM
CHOOSING THE MOTHER-TONGUE
Italian files group
English files group
ARCHIVE FUNCTION
'MARKET SEARCHING'
'SEARCHING'
'DRAWING OUT'
ACCESS KEYS
EUROPEAN CLASSIFICATION
S.I.V.A. CLASSIFICATION
Type
Use
Disabilities
Width - -
Scanning in the searching archive
YES
NO
'N' aids meet the requested features. Do you want to go on through other key ?
OUTPUT
Printout
RECORDING STATISTICAL INFORMATION
Are you satisfied with the result ? If you agree answer the question about your judgement.

When undertaking a retrieval operation the user is asked to choose the requested mother-tongue. The answer forces the program to access only the relevant group of auxiliary files.

The following operation are then possible:

1) "searching" the technical aids meeting particular requirements;
2) "drawing out" all information relevant to a particular product, whose record number has been found through the foregoing operation;
3) "market searching", locating manufacturers or suppliers dealing in a type of aid.

A "searching" operation may be performed using up to 26 access keys, falling into 3 groups:

- Nordic Classification codes (1 Key);
- General access keys for any aid;
- Particular access keys (14 keys) relevant to groups of aids with similar characteristics.

An example of the final printout is shown below:

```
*************************************************************************
Requested features of the technical aids:
-------------------------------------------------------------------------
Type:                                    WHEELCHAIR
The aid is of interest for persons with these disabilities:
* Difficulty in transferring from sitting to standing position
*************************************************************************
-------------------------------------------------------------------------
!                                                                       !
  N.  TYPE AND                         TRADE MARK              BIB.
      BRAND  NAME                                              REF.
!                                                                       !
-------------------------------------------------------------------------
 355 WHEELCHAIR                        [redacted]                        21
     CARROZZELLA<<ERETTA>>
-------------------------------------------------------------------------
 367 WHEELCHAIR                        [redacted]                        64
     LEVO-MOBIL
-------------------------------------------------------------------------
*************************************************************************
--------------- Number  of aids                             N.      2
*************************************************************************
```

The knowledge of the record number allows the drawing out of all the pieces of information needed for choosing the product:

```
S.I.V.A. -            SERVIZIO INFORMAZIONI E VALUTAZIONE AUSILI

                               MILANO, 20-DEC-83 H.14:43:57

************ S.I.V.A. DATA BANK OF TECHNICAL AIDS * RECORD N.    23
Type:                                   Stretcher
Brand name:                             165
Use:                                    Transferring
.........................................................................
The aid is of interest for persons with these disabilities:
Impossibility to walk
* Difficulty in using both legs
.........................................................................
Width        (mm)                        MIN.:    560       MAX.:    560
Length       (mm)                        MIN.:   1900       MAX.:   1900
Heigth       (mm)                        MIN.:              MAX.:    750
Material:                               Steel
Detachable
.........................................................................
Manufacturer:
***  16***          [redacted]
                    VIA IRPINIA.1/3                      TEL.  049/640398
                    35020          SAONARA                             PD
Supplier:
***  16***          [redacted]
                    VIA IRPINIA.1/3                      TEL.  049/640398
                    35020          SAONARA                             PD
.........................................................................
Bibliographic  Reference  code:                                       16
Price (lire):      352.000 TVA excl. under to date:    31-12-81
It is marketed in Italy
*************************************************************************
*  BARELLA AUTOSPINTA A 2 MANI PER PERSONE PARAPLEGICHE CHE DEVONO      *
*   DEAMBULARE DISTESE.                                                 *
*************************************************************************
Two-arms drive
Covering of the seat:                   Skay
Reclining backrest
Solid rubber front tires
Pneumatic rubber front ti-es
Solid rubber rear tires
Pneumatic rubber rear tires
Wheel number:                                                          4
Swivelling front wheels
Front wheel tire diameter                                            200
Rear wheel tire diameter                                             600
Independent brakes with direct lever handling
*************************************************************************
```

At present SIVA's data Bank includes 2500 aids clustered round 300 types, 400 manufacturers or suppliers, and is currently in use in Milan. Other centres in other regions of Italy are going to be set up in some months' time.

JOB ACCOMMODATION NETWORK (JAN): A SYSTEM TO INCREASE THE EMPLOYMENT OF HANDICAPPED PERSONS

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ABSTRACT - An informational system utilizing a comprehensive database to store employers' approved job accommodations has been established. Access to the data is through rehabilitation/human factors engineer consultants who translate an employer's job accommodation needs into operational strategies or techniques.

RÉSUMÉ - Un système informationnel utilisant des données de base complètes répertoriant des hébergements en fonction de propositions d'emplois agrées. L'accès aux renseignements est donné par l'intermédiaire d'une réhabilitation/facteurs humains des ingénieurs experts traduisent les besoins d'un employeur en matière d'hébergement en stratégies et techniques opérationnelles.

The employment of handicapped persons is usually associated with considerations that are not often of concern in the employment of non-disabled individuals. That is to say, an employer who wants to hire a handicapped person for a particular job or position must consider the specific nature of the tasks required by that job relative to the types of adaptations that may be necessary to accommodate the individual's functional limitations to those tasks. The job accommodations in question may range from the application of sophisticated devices to the minor modification of office furniture, and run the entire gamut of variations in between. In fact, something as simple as allowing a flexible work schedule may satisfy the work related needs of persons who may otherwise be unable to work due to disabling conditions.

The need to make job accommodations for a disabled individual is not limited to the initial hiring of that person. Rather, job accommodation also becomes a salient issue when considering the career mobility or advancement of a handicapped person.

From an employer's perspective, there are several incentives for providing job accommodations for the disabled employee or applicant. Premier among these is that in doing so, the employer may be securing the services of a competent and potentially productive employee. Job accommodation efforts can also have a direct financial benefit in terms of reduced worker's compensation or other insurance costs.

In spite of apparent benefits to an employer for making reasonable job accommodations, the need for such accommodations often serves as a major impediment to the employment and career mobility opportunities available to handicapped persons. To some extent, this is due to the perceived financial constraints. That is, some accommodations that might be applied to place a given handicapped person in a particular job situation may be so expensive as to simply prohibit the employer from implementing them. If this is the only accommodation known by the employer to be applicable in the given situation, this would typically be translated into a lost employment opportunity for the handicapped person (and perhaps for the employer). However, cost is not the major factor in most job accommodation decisions. This view is supported by a study performed by the U.S. Department of Labor (1982), and by a book recently published by the World Rehabilitation Fund and the Swedish Institute for the Handicapped (1983).

It seems likely that, from the perspective of the employer, a resource more limiting than funds is knowledge concerning job accommodation possibilities. That is, relatively few employers have been trained in topics concerning disabilities in the work place. Thus, few of them would possess an awareness of the job accommodation that might be applicable to a given situation. In the past, there did not exist in one place (or even in a few places) any consolidated resource to which an employer could turn in order to become aware of relevant options. Therefore, the cost factor affecting an employer's decision to perform a job accommodation is more likely the personal cost in time and effort associated with locating needed information. Hence, informational constraints concerning job accommodation options may be a predominant factor influencing the employment opportunities of handicapped persons.

The Job Accommodation Network (JAN) represents a solution to this problem. The network currently provides such information to users on a nationwide basis within the United States, and is being extended to international service with this presentation. The center of this network consists of a computer job accommodation database which has been used to catalogue and store data on job accommodations that have been field tested and proven to work by employers. The database also provides for the storage of general information concerning job accommodations, such as the names and addresses of individuals and organizations involved in the modification of work environments for disabled persons.

Access to the job accommodation database is performed through human factors/rehabilitation engineer resource consultants. These individuals are skilled in translating the employer's expressed job accommodation needs into specific, targeted job accommodation strategies or techniques. Employers using the network also have access to other information resources such as NARIC, ABLEDATA, Lockheed Dialogue, etc. Additionally, the system includes a network of experts in various aspects of job accommodation who serve as resource consultants in cases involving unusual or difficult accommodation problems.

The development of this system has been achieved through the collaborative efforts of the West Virginia Research and Training Center at West Virginia University, U.S.A.; the President's Committee for Employment of the Handicapped; the U.S. National Institute for Handicapped Research; and the U.S. Rehabilitation Services Administration; and by private industry within the U.S. This project represents the most comprehensive resource for job accommodation currently available in the United States. We believe it greatly enhances the ability of employers to perform reasonable and appropriate job accommodations for qualified handicapped persons. This, in turn, should result in a substantial increase in job opportunities for handicapped persons nationwide and internationally.

A Rehabilitation Information System

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ABSTRACT - The overall objective of this project is to provide an effective means of information exchange among individuals with disabilities and the professionals that serve them. To achieve this goal, a central telephone accessable, computerized database system is employed to accept, store, sort, and select data from/for the users. In operation, the user telephones the system to obtain information in the form of synthesized speech while the user's interaction is via the Touch-Tone telephone keypad. In this manner, these members of the rehabilitation community can participate in information exchange despite their geographic dispersion, varying abilities, and lack of traditional computer equipment.

NEED - The process of rehabilitation involves many people in many places. In the United States it is estimated that 36 million have some type of disability, including the two and a half million identified as being visually impaired. The problems facing both the individual heath care professional or the consumer can remain unsolved within this massive rehabilitation system. Alternately, the size of the community can become a positive resource within which a solution based upon the wealth of accumulated experience can be sought. In this manner, rehabilitation problems could be solved by people working in concert rather than individually. Information is the one force that can potentially bind concerned individuals into a community. Such a cohesive community does not now exist.

For disabled individuals the path from dependence to self-sufficiency is a difficult one. There are many important decisions to be made. Without a clear knowledge of the alternatives and their consequences, the wrong course can be taken.

PROBLEM - Local heath care professionals and consumers presently exchange information by a variety of means. Meetings, conferences, face-to-face discussions, telephone communication, newsletters, television and radio broadcasts, and books all promote communication among the individuals fortunate enough to participate. While some of these methods serve a wide audience, others are beneficial only to those who are at the right place at the right time. Diminishing travel budgets may limit participation at an out-of-town meeting, and printed newsletters may be inappropriate for individuals that experience vision impairments. Rehabilitation's many concerns makes it difficult for a solitary community member to keep abreast of its activities, current research projects, new devices, techniques, and aids, additional services, proposed legislation, employment opportunities, upcoming meetings and lectures, and current general information.

SOLUTION - It is the objective of this project to foster information exchange among individuals of the rehabilitation community, thereby producing an informed, interactive, and cooperative community. The barriers to such an informed community are no longer technological, but are related to the size, geographic dispersion, and varying ability (both financial and physical) of individuals to acquire data. The proposed computerized information system can eliminate these barriers. Its unique method of interaction with the users can facilitate information transfer between individuals despite their distance from the central system and their varying abilities to see, travel, and communicate. Thus, those that have been isolated can become a part of an electronically mediated community.

In actual operation, the user dials the number of the information system with any Touch-Tone telephone. Upon connection, a synthetic speech welcome message is presented - the system "talks" to the user. The system then queries the user on the need for familiarization. The user communicates a reply by pressing the appropriate Touch-Tone key. The computer recognizes which key was pressed and responds accordingly; by presenting or skipping the training. In this manner, the first time user can be "instructed" without human assistance.

A series of computer generated questions and user answers then leads the system to the message(s) containing the data that the user desired. These messages are then "spoken" by the speech synthesizer and heard by the user in the telephone receiver. Requests for messages about "mobility for the blind" or the "local meeting schedule", for example, can be fulfilled in this manner.

In addition, the user can enter a message into the system by a method that encodes two successive keypresses into the letters and numbers. The user can thus compose a request or enter information to the system as well as obtain data entered by others. Since a standard Touch-Tone telephone is utilized, no additional equipment is required at the user's end and the user deals with a devices that are widely available and which he/she is already familiar. To accommodate hearing impaired consumers and professionals, terminal and modem communication is also supported. The computer system thus mediates the information exchange among members of the rehabilitation community that are seperated by distance and physical ability, but have a common need for information.

In a very general sense, this information system can be considered a community communication aid that can satisfy the immediate informational requirements of the the local rehabilitation community.

To test this system, the local community of professionals and consumers have been invited to participate in the use, testing, and evaluation of the system. The success of the system will ultimately be judged by performing a controlled information exchange experiment with two groups of users, one with access to the system and one without.

Three specific areas of information exchange are being addressed in this study: device evaluation, employment, and information dissemination.

Device Evaluation: New rehabilitation devices have been obtained and their usefulness is being evaluated by a subject pool through the central computer system. The system in this context serves as an on-line evaluation facility, accessable at the both the user's and investigator's convenience. One specific device that is being evaluated is the information system itself.

Jobs Forum: The proposed system has the ability to aid an employment counselor in matching users' skills with existing job opportunities. Both unemployed visually impaired individuals and those companies seeking workers get together on the common-ground that the central computer system provides. An on-line job seeker's support group is also being formed.

Information Dissemination: The effectiveness of the system in providing periodic information for visually impaired individuals is being investigated. Specifically, an on-line newsletter serving this community segment has been started. Reader/author interaction is being promoted through the reader-question / author-response facility of the system. A computer/rehabilitation analog of 'Letters to the Editor' and 'Dear Abby' has been implemented.

The consumer portion of system users has been selected from among the two and a half million visually impaired and 60,000 blind individuals in the United States, a full third of whom live in the Western United States served by the Western Blind Rehabilitation Center. Their needs include device prescription, counseling, training, employment, and education. The system is attempting to address these immediate and long range needs of this population. Others associated with their care including physicians, family, neighbors, their parents and children, therapists, employers, educators, and device manufacturers are among the community of system users.

The following professional heath service organizations in the San Francisco area organizations serve the visually impaired population and have been invited to participate in this project: Veterans Administration Medical Center (Western Blind Rehabilitation Center, Palo Alto VA Rehabilitation Research and Development Center, and VA Regional Office Visual Impairment Service Team Coordinator), Smith-Kettlewell Institute of the Visual Sciences, University of California at Berkeley, Lighthouse for the Blind, Peninsula Center, and the Santa Clara Vision Rehabilitation Center.

This electronic bulletin board system demonstrates the techniques of synthesized speech output and Touch-Tone input. These techniques of man/machine interface will be applicable in other applications of information exchange, data collection, and dissemination. The system could be converted to use in areas other than rehabilitation. For example, an electronic conference could be produced in which the "speakers' presentations" would actually be edited computer synthesized voice messages to which the user would listen. The interactive nature of the system could accommodate questions by the listener and solicit an answer by the author of the paper. Such a conference, which could emphasize a particular aspect of rehabilitation, could last several months, with the obvious advantage that one could participate without physically traveling.

SUMMARY - The role of this system in providing information for the rehabilitation community can not be underestimated. Without timely, accurate data, people cannot make educated choices. Decisions based upon a lack of information or inaccurate data are decisions randomly made. Life without information in today's "Information Age" becomes one without plans or goals and ultimately without success, independence, or enjoyment.

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REGULATORY CONTROL OF REHABILITATIVE DEVICES IN CANADA

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ABSTRACT - Widespread use and technological developments in rehabilitative and other devices have resulted in hazards and concerns that require governmental control. Objectives and regulatory aspects of the Bureau of Medical Devices program to ensure safety, effectiveness and reliability of rehabilitative devices are described.

RÉSUMÉ - Les progrès technologiques récents et l'emploi répandu de dispositifs pour la réadaptation et autres fins sont une source de risques et d'inquiétudes dont le gouvernement doit s'occuper. On décrit les objectifs du Bureau des instruments médicaux et la réglementation qu'on y applique pour s'assurer que les appareils de réadaptation sont sûrs, efficaces et fiables.

INTRODUCTION

Potential and inherent risks posed by poor product quality, by the medical device itself or misuse of the product by the patient are some of the hazards associated with both current and future rehabilitative devices. Rehabilitative devices have become more sophisticated. With increasing knowledge of the hazards, the need for a corresponding variety of controls becomes understandable. The degree and extent of regulatory control of medical devices has also grown.[2,3,4,6]

In response to public demands, the Canadian Government's activities to ensure device safety have increased in scope and complexity over the past three decades.

REQUIREMENT FOR MEDICAL DEVICE REGULATION

Poor rehabilitative device quality may be hazardous due to faulty or inadequate design or testing, poor manufacturing control, improper use or incompatibility with other equipment. Major technical developments have occurred over the last decade with therapeutic and rehabilitative devices, diagnostic devices, prostheses and orthoses and a variety of aids. Many of these advances have resulted in deficiencies that have become apparent within a year or two of their introduction. Restraint and safety vests, widely used to limit patient movement and prevent injury have unfortunately, resulted in accidents and deaths. Radiofrequency diathermy units have caused patient injuries due to ignition of synthetics. These are examples where the Bureau has become concerned and issued medical alert letters. A wide variety of problems encountered with medical devices used in physiotherapy are being reported. Devices emitting electromagnetic and ultrasonic radiations may leak, exposing both operator and patient to unwarranted radiation. It has been estimated that over 80% of ultrasound therapy units in clinical use are in need of calibration. Hot packs, cold packs, electrical stimulators, ultraviolet lamps and traction apparatus are sold directly to the public. The labelling and need for calibration of all devices sold to the public which transfer thermal, electrical and electromagentic energies to the patient is ripe for review.

The nature of the hazards associated with rehabilitative devices poses problems that cannot be left to industry alone. Basic studies on fundamental mechanisms are likely to result in the development of new techniques for rehabilitative devices. The presence of a government supervisory agency to stand between industry and the marketplace, to regulate and monitor manufacturers and to inform and educate users is essential, if the public is to be protected from ineffective and hazardous medical devices or products. Such functions are performed by the Bureau of Medical Devices of the Health Protection Branch, Department of National Health and Welfare.[1]

Industry and the Bureau of Medical Devices have both recognized the fundamental responsibility of manufacturers for the safety of their products and the necessity of government regulation. The policy of discussing proposed regulations with industry before their introduction has been found to be highly beneficial, both in promoting industry cooperation through communication of the reasons for and intent of regulations and in providing feedback on their practicality. Because of an openness and flexible approach, there has been a relative absence of confrontation between industry and the Bureau of Medical Devices.

OBJECTIVES OF THE MEDICAL DEVICE CONTROL PROGRAM

The control of rehabilitative devices, carried out by the Bureau of Medical Devices aims to reduce patient death or injury from hazardous and ineffective medical devices; to increase occupational safety; to reduce health care costs; to improve utilization of device technology; to promote rehabilitative device research and development; to increase professional and public awareness of benefits and risks of devices for the disabled.

REGULATORY CONTROL

Medical device regulations were established in Canada in 1975 to carry out the purposes and provisions of the Food and Drugs Act. These regulations require: notification of what device is sold and by whom; proper labelling, including directions for use; availability in Canada of test results demonstrating safety and substantiating performance claims; records of user concerns, remedial actions taken, and recalls instituted; all of these apply to all types of medical devices. Standards for performance or disclosure of information have also been promulgated and rehabilitative devices are included amongst these.

Unfortunately deaths and injuries have occurred from knee braces which cause pressure on nerves, hip implants which fail, wheelchair front-wheel forks which break, heart valve prostheses which deteriorate prematurely, infusion pumps which cause air embolism and life support systems which fail to perform according to manufacturers' claims. For all such devices the potential problems are well recognized and specifications to limit undesirable characteristics can be set in standards. We believe that product class standards constitute the best method for assurance of safety, efficacy and reliability of most medical devices. Such standards are of benefit to both the user and the manufacturer. Standards are urgently needed for many device classes including traction devices, neuro muscular stimulators, hearing aids, respiratory care products, life support ventilators, infusion pumps, prostheses and other aids for the disabled sold directly to the public.

It is current vogue to argue for less government control and deregulation.[5] A number of serious concerns should be mentioned that balance this point of view: Rehabilitative devices are associated with changes in innovation and concepts, designs and materials. Older and sometimes obsolete technology continues to be marketed and used. An effective means of locating and dealing with such problem devices is by encouraging users to report rehabilitative device related problems, failures and accidents. No formal system currently exists in Canada to collect reports of rehabilitative device failure or related deaths and injury for analysis and resolution. A global dearth of safety and performance standards for rehabilitative devices exists.

PRINCIPAL TECHNIQUES FOR CONTROL OF REHABILITATIVE DEVICES

The principal techniques for control of rehabilitative devices are: pre-market review of new devices; development and implementation of mandatory performance or disclosure standards; verification of manufacturer's claims, research and evaluation and investigation of user concern reported voluntarily.

Pre-market review at present is only applicable to new implantable devices. It includes the evaluation of submissions from researchers, innovators, or manufacturers. These submissions contain information and material to substantiate that the device has been adequately tested to demonstrate safety and has a high probability of effectiveness.

Quality standards are developed to serve as proxy indicators of product safety and effectiveness. International rehabilitative device standards are not readily available and must be developed.

CONCLUSION

The regulatory philosophy is based on the premise that there be close harmony and cooperation from those that use the rehabilitative devices and those that produce them. Such joint expertise will result in a balanced and effective approach to understanding and applying the regulations associated with rehabilitative devices and a healthy outlook for the future.

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BRIDGING THE GAP BETWEEN RESEARCHERS AND DEVELOPERS OF TECHNOLOGIES AND THE DISABLED PEOPLE WHO USE THE TECHNOLOGIES

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ABSTRACT - This paper describes a long term project of the American Association for the Advancement of Science which attempts to expand the interest of the scientific and engineering communities in research and development of technologies for disabled persons. Specific activities, regional workshops, Bulletins, research review and consortium development are described.

RÉSUMÉ - Cette communication décrit un projet à long terme de l'American Association for the Advancement of Science qui vise à accroître l'intérêt de la communauté des scientifiques et des ingénieurs pour la recherche et le développement en matière de technologie pour les personnes handicapées. On décrit des activités précises, des ateliers régionaux, des Bulletins, une étude de la recherche qui se fait dans le domaine ainsi que la création d'un consortium.

Since 1975, when the concerns of handicapped individuals in science were brought to the attention of the American Association for the Advancement of Science (AAAS) by a deaf biologist member, AAAS Project on the Handicapped in Science (PHS) has been a national center of information on handicapped persons in science. The Project on the Handicapped is part of the AAAS Office of Opportunities in Science. A major thrust of the Project since its beginning has been the development of a Resource Group of Disabled Scientists. This group now numbering over 1,000, consults on matters of handicapped individual's access to science education, architectural and laboratory accessibility, professional meeting accessibility aids and equipment, and barriers to employment. All activities of the Project on the Handicapped in Science are directed toward the interrelationship of science and disability.

In 1980, the Project on the Handicapped in Science began a program to increase the interaction between disabled and ablebodied scientists and engineers working on science and technology for the handicapped. A three-year series of regional workshops, Bulletins disseminated nationally and other activities planned to bridge the gap between researchers and developers of technology and the disabled people who are potential users of the technologies, were funded by the National Science Foundation (NSF) through its Program of Science and Technology to Aid the Handicapped. The impetus for the workshops was based on a need to expand the findings of an earlier NSF-funded AAAS/PHS project and its resultant publication A Research Agenda on Science and Technology for the Handicapped. This agenda identifies priority research needs in science and technology for disabled individuals and suggests the type of exchange between disabled and non-disabled people which would result in effective research and development strategies to meet current pressing needs of handicapped people and to improve their quality of life.

The workshops provided a unique opportunity for disabled and non-disabled scientists and engineers to participate in the process of identifying current research, outlining requirements for innovation development, proposing new programs of research in technological aids, and methods of effectively sharing state-of-the-art information on devices to avoid re-invention of the wheel, and the wheelchair. Joining the scientists and engineers in their discussions were disabled consumers, parents of disabled youth, architects, designers, manufacturers of aids for disabled persons, physicians, nurses, occupational and physical therapists, rehabilitation counselors and administrators, communication specialists, representatives of small business and the insurance industry, and educators at the pre-college level. Each workshop had its own particular mix of individuals, reflecting both the institutions of the region, the existing educational, employment, and recreational opportunities, and the networks that had previously developed. One of the major goals of the workshops was to expand these networks, to initiate communication between individuals from institutions that were within "shouting distance" of each other but were separated by traditional historical and attitudinal barriers. The workshops also provided a platform for private individuals who were independently developing aids and devices with an opportunity for interchange with institutionally-affiliated persons researching in the same area. Notices in Science magazine alerted a wide audience of people to inquire about the workshops; many of these people were not part of the formal discipline of rehabilitation engineering and were able to bring experience from a different prospective.

Because the main objective of the workshops was to actively involve disabled persons in research and development of science and technology for the handicapped, a special effort was made to include a significant number of disabled people in each group of participants. Invitations were issued through local disabled consumer groups, organizations, disabled student officers on university campuses, and the AAAS Resource Group of Handicapped Scientists. Registration for each workshop was planned to include a wide representation from institutions of the region and also allow for unexpected registrants representing lesser known or newly established groups.

The workshops were designed to be highly participatory. At the final session of each workshop, all registrants gave oral presentations of their own action plan developed during the course of the meeting. The action plans were not recommendations for a government bureau or outside agency to implement--they were individual practical proposals of activities to be carried out in the near future by the participants themselves in their own environment--university, laboratory, hospital, business, or community-at-large. Participants were encouraged to use the resources of AAAS to carry out their plans and to inform AAAS of their progress by sending notes to the information exchange of the Bulletins. Action plans were often made by groups of participants from different institutions in the same geographical area who had discovered at the workshops that they were working on parallel tracks in seeking solutions to problems.

The Bulletins, published by AAAS, report on selected speeches and small group discussions from the workshops. In addition, the Bulletins contain notices of current and proposed research in technology, announce the most recent NSF grants on science and technology to aid the handicapped, and give details of new products, other meetings, and available resources. The Bulletins have been a vital link in joining the various target groups throughout the country, and allowing for individuals to write in relevant comments and share information about new resources.

At present, the AAAS Project on the Handicapped in Science is working to create an even more useful system of information exchange. The Project is working closely with the 286 scientific and engineering societies and academies of science that are affiliated with the Association as well as drawing heavily on the expertise provided by the over 1,000 disabled scientists and engineers who are members of the AAAS Resource Group.

As a first step, the Project is reviewing completed and ongoing research and development work to aid handicapped persons. This includes identifying research projects funded by the NSF and other federal agencies, searching scientific literature to locate other disability related R&D projects, and organizing information from disabled user groups and individuals.

To encourage awareness of research opportunities in the field and more cross-disciplinary research, the Project will form a consortium of associations to address science and technology to aid the handicapped. Consortium members will share information and successful strategies they have developed to assist the disabled.

The Project on the Handicapped in Science hopes to call attention to the field of disability research and to expand the benefits it offers to disabled individuals in the R&D process, and increasing the public's awareness of these issues.

SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 18

BIOFEEDBACK THERAPY/
TRAITEMENT PAR LA RÉTROACTION BIOLOGIQUE

A FEEDBACK MECHANISM FOR USE IN PARAPLEGIC STIMULATION TECHNIQUES

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ABSTRACT - A concept employing electromagnetic, six-degree-of-freedom, position and orientation measurement technology is advanced for providing real time feedback data for use in paraplegic stimulation techniques. Accurate measurements can be made to optimize time and frequency of the stimulation signals.

RÉSUMÉ - Un mécanisme basé sur la technologie de la mesure électromagnétique des positions et orientations suivant six degrés de liberté est perfectionné en vue de fournir des données en temps réel sur les rétroactions de systèmes utilisant des techniques de stimulation des paraplégiques. Des mesures précises peuvent être effectuées pour optimiser le moment et la fréquence des stimuli.

INTRODUCTION

This paper describes an electromagnetic feedback mechanism that can provide, in real time, the position and orientation (i.e., six-degree-of-freedom) of a predesignated portion of a limb reflecting the aggregate desired action relative to a fixed reference point. Utilizing this technique, exact stimulation can be accomplished in real time. Concurrently, accurate measurements of response could be made in a training-oriented situation, with the purpose of refining stimulation signals, in real time, to achieve optimum performance. Integration of the electromagnetic six-degree-of-freedom measurement technology with functional electrical stimulation techniques can provide a system that is precise, lightweight, compact, rapidly applied, simple to operate and cost effective.

ELECTROMAGNETIC MEASUREMENT TECHNOLOGY

Electromagnetic measurement technology uses low frequency (2-14 kHz) magnetic fields to measure position and orientation of one object in relation to another.

The position of a point in space is fully described by its relationship to any fixed three-axis (X, Y, Z) coordinate system. Orientation in relationship to that position can be fully described by three angles known as azimuth, elevation, and roll (ψ, θ, ϕ).

Consider a system consisting of a fixed, magnetic-dipole transmitting antenna called a source; a freely moveable, magnetic-dipole receiving antenna called a sensor; and associated electronics. Both the source and sensor antennas consist of three mutually orthogonal loops.

Each loop of the source antenna is excited with a driving signal identical in frequency and phase. The source antenna excitation is a pattern of three states. Exciting the source results in an output in the sensor of a set of three linearly independent vectors. The three output (sensor) vectors contain sufficient information to determine the position and orientation of the sensor relative to the source. Nine measurements are thus available to solve for six unknowns; namely, X, Y, Z for position and ψ, θ, ϕ for orientation.

The sensor is small (0.59-in. cube) and lightweight (0.5 oz). The source assembly measures 1.8-in. high by 1.7-in. square, and weighs 8.6 oz. The system provides hemispherical measurement capability with a radius of 32-in. and angular accuracies in excess of 0.5° at the 50% confidence level throughout a compensated operational envelope. System resolution is typically 0.1° angular and 0.05-in. translational. Measurements are made and output at a rate of 60 times per second for a single source and sensor. Outputs may be serial ASCII, 9600 baud asynchronous RS-232C, or serial binary asynchronous RS-232C at 9600 baud. The technology has been reduced to practice in both militarized and commercially available Tracker units. As a helmet-mounted sight, the technology is used in fighter aircraft and in flight simulation systems. It is also used in a new communication aid for non-vocal severely handicapped persons.

CONCEPT

The feedback mechanism concept presented is applicable for use on any limb. However, for ease of description, consider a system used in a training/exercising situation for stimulation of a person's paralyzed leg to effect taking a single step. Consider further that the musculature for stimulation has been selected and the excitation signals preprogrammed for time phasing, frequency and amplitude.

Under these conditions, a block diagram of the system is shown in Figure 1. The sensor is mounted on the dorsum of the foot and attached to a 3SPACE Tracker electronics unit via a 10-ft cable. The source, i.e., fixed reference, is

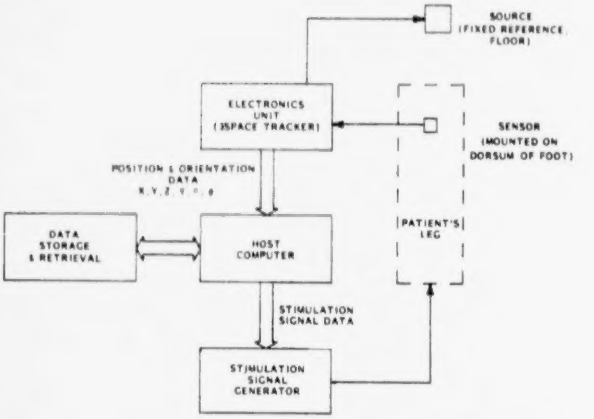
SOURCE (FIXED REFERENCE FLOOR)
ELECTRONICS UNIT (3SPACE TRACKER)
SENSOR (MOUNTED ON DORSUM OF FOOT)
POSITION & ORIENTATION DATA X,Y,Z,ψ,θ,φ
PATIENT'S LEG
DATA STORAGE & RETRIEVAL
HOST COMPUTER
STIMULATION SIGNAL DATA
STIMULATION SIGNAL GENERATOR

Figure 1. Paraplegic Stimulation with Electromagnetic Feedback--Block Diagram.

mounted on a short wooden pedestal at a convenient reference position relative to the plane of the step and electrically connected to the 3SPACE Tracker via a 10-ft cable. The output of the electronics unit is connected via an RS-232C serial port to a host computer. Assuming a 22-in. stride and preprogrammed stimulation signals, the exercise can begin. Figure 2 shows, in lateral view only, five (5) positions of a normal step with a 22-in. stride.

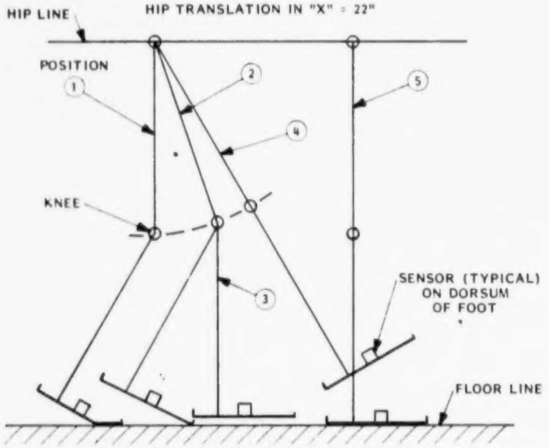
HIP LINE
HIP TRANSLATION IN "X" = 22"
POSITION
1
2
3
4
5
KNEE
SENSOR (TYPICAL) ON DORSUM OF FOOT
FLOOR LINE

Figure 2. Five Positions of a Step, 22-in. Stride--Lateral View Only.

From a start position (position 1 of Figure 2), the Tracker will indicate the six-degree-of-freedom parameters at a rate of 60 measurements per second. As the stimulation process continues, measurements taken at the sensor may be compared in the host computer to an ideal (desired) six-degree-of-freedom location of the foot. Based on comparisons of the ideal and the actual data, the time phasing, frequency and amplitude of the excitation signals may be varied by commands from the host computer to the stimulation signal generator, and thus to the proper muscles for correction. From position 4 to position 5 of Figure 2, the hip must be translated in "X" to complete the step. At this point, a reverse process may be initiated to recover to the starting point and the exercise repeated.

The table that follows indicates probable values of the six-degree-of-freedom parameters relative to the five step positions shown in Figure 2. For this table, taken from an appropriate layout of the five positions of a step in a lateral view only, the "Y" position is assumed constant. Azimuth and roll are also assumed to be constants. Admittedly, these parameters (Y, ψ, and φ) may vary within the step plane. The amount of variation for Y and ψ is assumed to be small. Roll (φ) may vary significantly as a function of pronation or supination relative to the hip translation in the transition between positions 4 and 5.

SENSOR OUTPUT - STEP POSITIONS

NUMBER	POSITION (INCHES)			ORIENTATION (DEGREES)		
	X	Y	Z	ψ(AZIMUTH)	θ(ELEVATION)	φ(ROLL)
1	+30.5	+4.0	+8.0	0°	+34°	0°
2	+22.0	+4.0	+7.0	0°	+37°	0°
3	+12.0	+4.0	+8.0	0°	0°	0°
4	+1.0	+4.0	+4.5	0°	-35°	0°
5	0	+4.0	+9.0	0°	0°	0°

The amount of data taken during a single step indicates that the rate of measurement is sufficient for this stimulation scenario. It was assumed that with a 22-in. stride, a training rate of 50% of normal walking speed would be sufficient; i.e., 1.5 miles per hour. At this rate (2.199 ft/sec), all six parameters are measured every 0.439 in. of travel.

CONCLUSIONS

It can be seen that by employing electromagnetic measurement techniques as a feedback mechanism in an electrical stimulation scenario, accurate refinement of the stimulation signals may be obtained through closed loop operation. The electromagnetic technique provides simple, precise, six-degree-of-freedom measurements at a rate sufficient for use in a training and exercise environment.

RECOMMENDATIONS

It is recommended that this technique be evaluated by the academic/biomedical community through in-vivo testing. Necessary refinements in the system may be accomplished using inputs resulting from the testing to effect established needs for a feedback mechanism for paraplegic stimulation techniques.

REFERENCE

1. J. C. Krieg, "Electromagnetic head tracking, a new communication device for persons who are severely disabled," Proceedings of the Interagency Conference on Rehabilitation Engineering, pp. 23-31, Atlanta, Georgia, August 26-31, 1979.

SWALLOW IDENTIFICATION BY INFRA-HYOID ELECTROMYOGRAPHIC SIGNAL ANALYSIS

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ABSTRACT - A technique for identifying a swallow by analysis of the electromyographic pattern recordings of the infra-hyoid group of muscles has been developed and tested with a group of normal, school-aged children, facilitating the determination of unconscious swallowing frequency.

RÉSUMÉ - On a mis au point et testé chez un groupe d'enfants normaux d'âge préscolaire une technique pour identifier la déglutition au moyen de l'analyse électromyographique du groupe de muscles infra-hyoïdiens et permettant de déterminer plus facilement la fréquence de la déglutition inconsciente.

Introduction

Swallowing is of interest to researchers at the Ontario Crippled Children's Centre because of its relation to drooling. Oral-motor dysfunctioning and an inadequate swallowing rate are said to be the primary causes of drooling. Early studies of drooling, preliminary results and their implications have been presented previously^2.

The first phase of the research, recently completed, has provided a data base for the development and application of a software technique to analyze infra-hyoid muscle electromyograms so that swallows may be identified and recognized from a long-term (1/2 hour) recording. With this type of information, the hypothesis concerning a lower resting swallowing frequency in children with cerebral palsy can be tested.

Swallowing is an automatic reflex, initiated both voluntarily and subconsiously, intimately related to respiration, and ultimately necessary for survival. Traditionally it has been studied by pressure manometry to determine the temporal pressure gradients between the oral cavity and esophageal opening, by needle electromyography to map sequencing of the muscles recruited for swallowing, by cine-radiography to observe bolus manipulation through the oral-pharyngeal and esophageal stages of swallowing, and by audio-recording from a microphone over the larynx for swallow sounds. The first three techniques are invasive and are not appropriate when working with young children with cerebral palsy. Audio recordings of swallowing sounds are useful when trying to confirm a swallow but, when the subject is spastic or athetoid, microphones are difficult to attach and the recordings are laden with movement artifact noise, which is difficult to differentiate from pharyngeal swallowing sounds.

Surface electromyographs from the infra-hyoid group of muscles revealed a consistent and definitive peak every time a swallow occurred. It was upon this fact that the analysis technique was developed, since it was possible to differentiate swallowing signals from movement artifact.

Methodology

The study protocol required that the EMG patterns of three groups of 12 children each be studied: a normal group, a group of children with cerebral palsy who do not drool, and a group of children with cerebral palsy who drool. EMG patterns of the infra-hyoids were recorded from a set of Beckman miniature surface electrodes by an Autogen 1700 Feedback Myograph. The signals were band pass filtered from 100 - 200 Hz, full-wave rectified, integrated over 50 ms, and recorded by an FM tape recorder.

Specific drinking tasks, each lasting seven seconds, were performed by the children so that EMG swallow patterns could be determined. Swallowing rates were then determined by examining 1/2 hour recordings, in search of EMG patterns matching those of the specific drinking tasks. The tasks protocol consisted of recording baseline EMG, recording a single sip and swallow of 5 ml of liquid, three distinct, rapidly successive sips and swallows totalling 15 ml, and the continuous drinking of 75 ml of fluid. Long-term recording was done over a 1/2 hour period while the children watched television.

The integrated EMG (IEMG) from each drinking task was sampled by a Tektronix 4052 microcomputer at 50 Hz and processed to derive peak pattern information. Peak parameters included baseline IEMG (uV), threshold IEMG (uV), peak width (s), average and peak IEMG amplitude (uV) and the area under the peak curve (sum of all raw data points in the peak). Parameters were derived for individual sessions and individual subjects due to the sometimes extreme variation between subjects and sessions.

Swallowing frequency was determined by entering the peak parameters for a specific session's drinking exercise into a PDP-11/34 minicomputer, scanning the 1/2 hour recording at 16 times real-time for matching peaks, and counting the detected peaks.

Analysis

Initially, before any peak parameters could be determined, the average IEMG value was calculated from the baseline or relaxed state recording. Looking at a specific drinking task point by point for seven seconds of data points, all of the points greater than the baseline were summed and then averaged. The baseline value and the average value of the points greater than baseline were summed and called the "threshold". Rather than setting the threshold arbitrarily as a multiple of the baseline, it was decided to use the approach of the baseline plus the average of values greater than baseline due to the information concerning movement artifact inherent in the main signal. The EMG signal of a swallow is superimposed upon an EMG signal generated by movement of the head, neck and/or shoulders. Therefore, if there was movement present during a swallow, a higher threshold would result from the larger number of points greater than the baseline value but this threshold will still detect a peak due to a swallow. Conversely, little movement creates a lower signal amplitude providing a lower threshold.

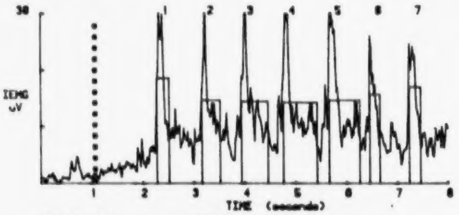
The data points are re-examined a second time from the beginning point-by-point, being tested to see whether they are greater than threshold. If a minimum of five successive points equivalent to a period of 0.1s, are greater than threshold, that group of points is considered to be part of a peak. Preliminary evidence showed that IEMG swallow peaks lasted longer than 0.2 S, while movement artifacts often were faster than 0.1 S in duration. The time at which the threshold is crossed in a rising step is considered the start of the peak, while the second threshold crossing, the dropping edge, is the finish time of the peak. The period between these two points is the peak width. The area under the peak curve over the threshold is calculated, and represents the strength of contraction.

The median of area under the peak curve is called the centroid and is considered to be the time of maximum activity. It is this time that is used in the calculations of the time interval between consecutive swallows. The maximum amplitude (uV) of a peak signal is also recorded for comparison.

During each individual session each drinking task was repeated several times so that an average value for the various parameters could be derived. These parameters for each individual subject and session were subsequently used for a particular session's analysis of the 1/2 hour "quiet sitting" in search of the "unconscious" swallowing frequency. The parameters used were: minimum peak width (s) (less one standard deviation (s.d.)); maximum peak width (s) (plus one s.d.); threshold as derived from the single sip and swallow task; maximum peak amplitude (uV) (avg. max. + 1 s.d.); minimum interval between swallows (minimum centroid to centroid interval as determined by the continuous drinking task); and, minimum and maximum peak curve areas (minimum - 1 s.d. and maximum + 1 s.d. respectively).

In order to account for changes in baseline IEMG due to longer term electrode placement, sweat, and basal changes in muscle activity (as opposed to activity due to specific movement), the 1/2 hour analysis was performed over a "running baseline". That is, a baseline was calculated based on the first ten seconds (real-time) of recording and beyond that, was continuously updated (i.e. add the new value at the front end of the analysis, drop the first value in the string and average the sum over 10 seconds).

Analysis of the 1/2 hour sessions was done using a PDP-11/34 computer because of its capacity for high speed data sampling and A/D conversion.



SUBJECT: DO SESSION: 4
SCAN: 8 CHANNEL: 3
BASELINE IEMG: 1.80uV THRESHOLD IEMG: 10.10uV

PEAK	LOC.	WIDTH	CENT.	AREA	AVG.	MAX.
1	2.20	0.29	2.30	241	16.5	30.0
2	3.10	0.38	3.31	270	14.0	33.5
3	3.84	0.54	4.15	380	14.4	32.3
4	4.78	0.60	5.02	485	14.3	30.9
5	5.66	0.62	5.80	454	14.0	34.3
6	6.40	0.22	6.54	173	15.7	20.5
7	7.24	0.24	7.33	204	17.0	24.5

Figure 1: Analysis of IEMG of infra-hyoids during continuous drinking.

Results and Discussion

Figure 1 displays typical results of the analysis of the IEMG of continous drinking of 75 ml of juice by a normal subject. Although all parameters were grouped and averaged in various configurations (e.g.: male vs. female, single-sip parameters vs. continuous drinking parameters, etc.) to obtain generalized trends, an individual session's parameters from the drinking tasks were utilized for that same session's 1/2 hour analysis for optimal results. In general, the peak widths ranged from approximately 0.4s to approximately 1.2 s. The IEMG threshold detection level was approximately 6 times the average baseline value, while the peak IEMG amplitudes were approximately 20 times the basal IEMG.

Applying the voluntary task swallow parameters to the unconscious 1/2 hour swallow recordings, swallowing frequencies for normal children of between 6 and 21 swallows per hour were calculated. This falls just short of the estimated adult swallowing rate during "usual indoor activities" recorded by a laryngeal microphone of approximately 28 swallows per hour[1].

Presently this IEMG analysis technique is being used to determine whether children with cerebral palsy who drool, do so partially because of a depressed unconscious swallowing frequency.

Acknowledgement

This work is supported by a grant from the Ontario Ministry of Community and Social Services. The assistance of Prof. H. O'Beirne is gratefully acknowledged.

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A NEW ANALYSIS OF ISOKINETIC EXERCISE AND A TRIAL OF BIOFEEDBACK

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ABSTRACT - Clinical application of Cybex (isokinetic exerciser) is limited with difficulty to analyse the data. A trial of data analysis was done with multivariate analysis of 30 variables selected from two waves (Torque and Angle). Biofeedback application was performed.

RÉSUMÉ - L'application clinique de Cybex (exerciseur isocinétique) est limitée par la difficulté à analyser les données. On a effectué un essai d'analyse de 30 variables choisies dans deux groupes d'ondes (couple et angle). On a ensuite procédé à des essais de rétroaction biologique.

PURPOSE : Cybex was developed with new concept of isokinetic exercise. It has been used rather in the gymnatic field as the muscle training machine than in the medical field. Cybex needs to have full range of motion in the joint and maximal effort of subject for exercise. However, those who need to have therapeutic exercises would have limited motion of joint, pain on motion and/or anxiety to push themselves on exercise. Torque and angle wave forms are extremely variable in these pathologic conditions. The analysis method available at the present time is not suitable for those conditions. Our investigation of Cybex is to use Cybex as a practical evaluation tool in clinical field.

METHOD : The present method of data analysis is shown in Fig.1. Data have been analysed mostly manually with measurement of peak torque. This methods made it difficult to utilize Cybex in clinical application.

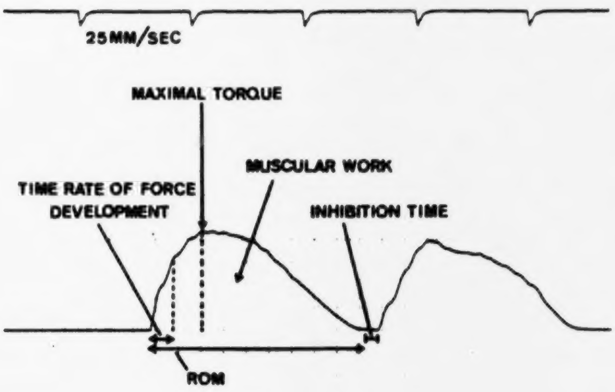
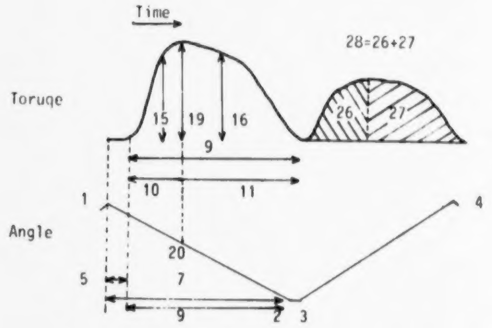


Fig. 1. The present method of data analysis.

Our approaches are the following three points.
(1) We selected 30 variables from two wave forms from Cybex to ditermine the important ones and the cluster analysis was used (Fig.2).
(2) The microcomputer system was applied for prompt collection and processing of data.
(3) To instruct the target "point" on effort, a biofeedback unit was fabricated.

Clinical studies were conducted to proof the above approaches were clinically practical. Study exercise is flexion and extension of knee joint.



1. Angle 1
2. Angle 2
3. Angle 3
4. Angle 4
5. Delay 1
6. Delay 2
7. Ex. time
8. Fl. time
9. Ex. dur. t.
10. Ex. dur.Pre.P.t.
11. Ex. Dur. post P. T.
12. Fl. Dur. T.
13. Fl. Dur. Pre.P.T.
14. Fl. Dur. Post P.T.
15. Ex. 30° Torque
16. Ex. 60° Torque
17. Fl. 30° Torque
18. Fl. 60° Torque
19. Ex. Peak Torque
20. Ex. Peak Angle
21. Fl. Peak Torque
22. Fl. Peak Angle
23. Ex. Pre. Work
24. Ex. Post Work
25. Ex. Total Work
26. Fl. Pre. Work
27. Fl. Post Work
28. Fl. Total Work
29. ROM 1
30. ROM 2

Fig. 2. Definition of 30 variables from two wave forms.(FL=Flexion, EX=Extension)

EQUIPMENTS : Cybex (Lumex Company) was used as the main instrument (Fig. 3). Personal computer, IF800 model 30 (OKI COMP. Z80B) was used for acquisition and processing of data from Cybex. Sampling rate was changeable with the variable speed of Cybex(RPM) Output can be optional to compare 2 variables. Biofeedback unit (audiosignal) was fabricated for clinical use and the sources of the feedback are adjustable thresholds of the peak torque and the angle of range(Fig. 4).

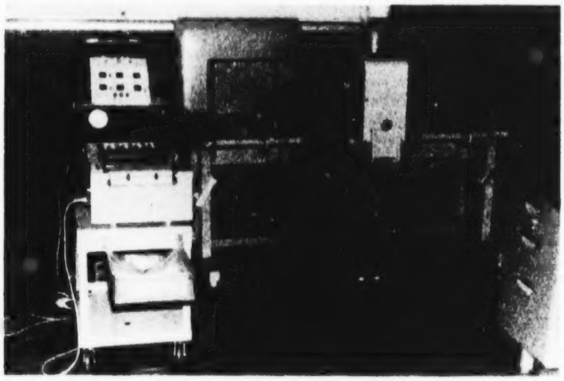


Fig. 3. Cybex machine and biofeedback unit.

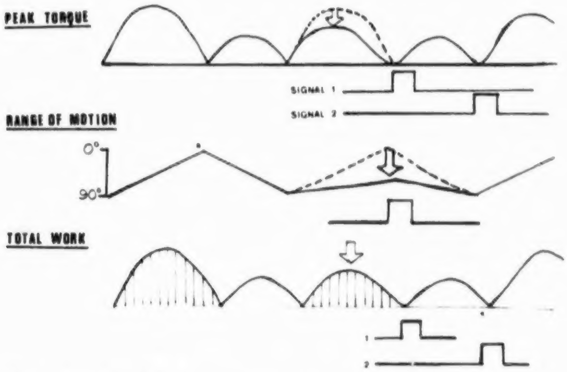


Fig. 4. Feedback sources in Cybex.

RESULTS : Cluster analysis was performed from 4 normal subjects and 4 patients with orthopedic diseases of knee joint. 30 variables were divided to four large groups represented by peak torques both in extension and flexion and ROM (range of motion) of extention and flexion. Delay time, which is the lag time between when the angle curve starts and when the torque curve starts, is the important variable to differentiate normal and pathologic conditions (Fig. 5,6).

20 young normal male subjects were tried for biofeedback. 50 repeated knee extention and flexion were performed at 25,15 and 5 RPM. Biofeedback application is found out to be effective to keep the peak torque high for longer time above the threshold peak torque compared to without feedback (Fig. 7).

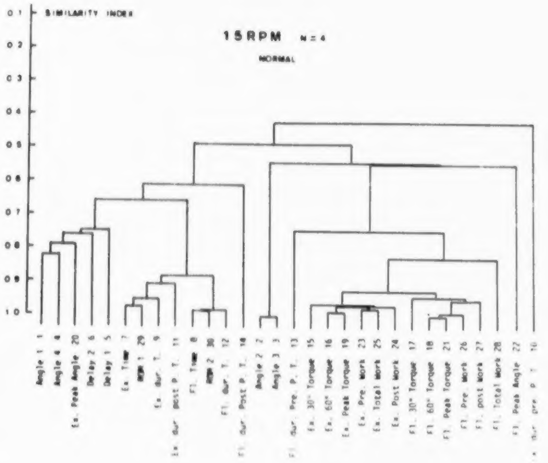


Fig. 5. Cluster analysis with 4 normal subjects.

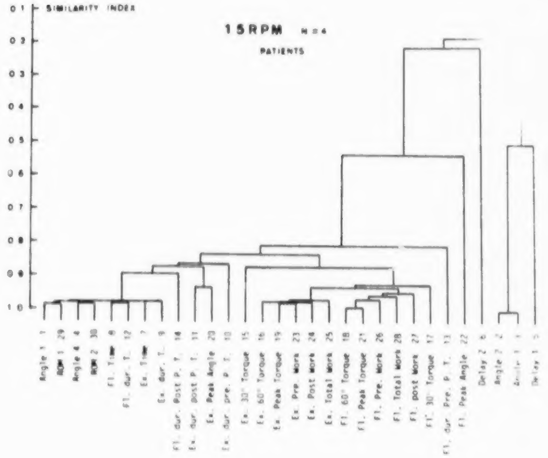


Fig. 6. Cluster analysis with 4 patients.

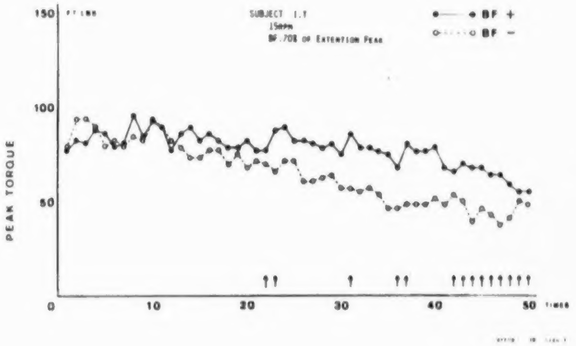


Fig. 7. An example of biofeedback application.

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THE USE OF THE MICROCOMPUTER IN THE REHABILITATION MEDICINE

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ABSTRACT - This paper describes a training regime for the treatment and evaluation of patients with neuromuscular disorders. A patient is asked to control his myoelectric activity by watching the processed signals on a TV screen.

RÉSUMÉ - Cette communication décrit un régime d'entraînement physique pour le traitement et l'évaluation des malades atteints d'une affection neuromusculaire. On demande au sujet de contrôler son activité myoélectrique en surveillant les signaux traités sur un écran de télévision.

For the purpose of training neuromuscular disorders and for the purpose of a better goalsetting of the treatment and evaluation of the patient's progress we are using a multichannel emg-set with a microcomputer. The emg-signals of two or four muscles are picked up by special electrodes, which are vacuumed-connected to the skin. These electrodes are part of a preamplifier, which reduces undesirable artifacts. The next steps of processing the signals are: filtering, amplifying and integration. After integration a microcomputer uses the moving-average method in the software to obtain a smoothed curve with an adequate resolution. The myoelectric activity of two muscles is plotted real-time on the tv-screen. It is important to notice, that a commercially available emg-design can also be connected to the Apple-microcomputer. During each trial the patient can see his own emg-signal on the tv-screen. This signal changes proportional with his own effort, so he can manipulate this signal for getting a better control of his motor-behaviour. The patient can train with one channel to increase the myoelectric activity, while training with the second channel to reduce undesired activity. A goal line can be set by the therapist at a desired level at the tv-screen. The four channel option is used for research-purposes with one microcomputer input used for a muscleforce or footswitches registration.

COMPUTER-ASSISTED NEUROSURGERY: A USER INTERFACE FOR WIDESPREAD USE

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ABSTRACT - In this paper we describe a computer program designed to assist stereotaxic neurosurgery for the relief of involuntary tremor and intractable pain. We describe the user interface which we have developed to make the program widely available to users without previous computer experience.

RÉSUMÉ - Dans cette communication, nous décrivons un programme machine visant à assister la neurochirurgie stéréotaxique pour le soulagement des tremblements involontaires et des douleurs insoutenables. Nous décrivons l'interface que nous avons mise au point dans le but de faciliter l'utilisation du programme par des usagers n'ayant pas d'expérience préalable des ordinateurs.

In this paper we would like first to describe a computer program used to assist in stereotaxic surgery. Stereotaxis is a neurosurgical procedure which is used to eliminate involuntary tremors caused by nervous disorders such as parkinsonism, multiple sclerosis and dystoria. It is also undertaken for the relief of intractable pain such as that caused by terminal cancer or associated with an amputated limb. The procedure is carried out by the insertion of an electrode into that part of the brain which, through the probing of subcortical brain structures with mechanically directed instruments, is found to govern the tremor or pain, and by the creation of a lesion at that point, that is, by its destruction electrically.

As might be guessed, in the early years of its use, that is, in the 1940s, this procedure was somewhat dangerous. The difficulty of pinpointing the exact place within the central nervous system where the lesion was to be made placed the patient at considerable risk. The precise localisation of the lesion site was, and, indeed, still is, hampered by the fact that each human brain is a little different from the next, and, similarly, that structures vary even within any one brain. The precision of the surgical apparatus has, of course, undergone considerable improvement since those early days, but, though lessened somewhat, the difficulties remain.

In the mid-1950s it was shown that destruction of vertical lateral thalamic nuclei reduced the tremors and rigidity associated with parkinsonism; from this point, most work in stereotaxic surgery centred on that part of the brain known as the thalamus. During this period, it was also decided that, in order to avoid the high risk of damage to central nervous system structures which was the consequence of an open-operative approach, the lesion site should be located through its spacial proximity to well-known landmarks within the brain which could be identified radiographically and referred to a co-ordinate graph. The position of the lesion site which had been determined radiographically could then be checked neurophysiologically, in fact by recording the patient's responses to electrical stimuli.

The desirability of representing this material visually to the surgeon led to computer involvement in the stereotaxis procedure. Certain electrical stimuli produce a common response in all patients, and it was felt that if these could be represented graphically, this would enable an electrophysiological map to be made of the human diencephalon. This topographical map would show the general distribution of nuclei within the brain, and the organisation of general sensory nuclei and motor responses. The brain in question would be a generalised or averaged brain since, as mentioned above, each brain differs somewhat from the next. It was felt that a visual map of these data would be helpful in the understanding of the central nervous system. Moreover, it promised to be useful in the precise determination of the lesion site and in the acquisition of data for research into the variations between different brains, with a view to reducing the possibility of error in the localisation of the lesion.

The program [1] was developed in 1975 and began to be used to assist stereotaxic surgery at the Toronto General Hospital. Data concerning the location of the stimulating electrode and the "hallucinations" or responses evoked by the stimulation would be entered into the computer for future analysis and a graphical representation of these data would be printed out for use in the particular operation. At the time this meant that the printout had to be collected from a mainframe computer at the University of Toronto and taken to the hospital so that the surgeon could use it in determining the lesion site. As this commuting clearly held up the operation considerably, the program was modified so that the graphical, that is, visual, representation of the data could be seen immediately on a graphics terminal in the operating room.

To aid your understanding of the procedure, we shall give here an outline of the operation itself. At the beginning of the operation, a LEKSELL frame is fitted to the patient's skull in order to eliminate movement of the head. A hole is made in the skull to make possible the placement of the electrode. Through x-rays, specific brain structures, already familiar to the surgeon, are located and measured. These structures are used as reference points in the exploration for the appropriate lesion site. From their measurements, an operative template, that is, a map, of the brain is created. In doing this, the program accommodates any variation from the norm in the patient's brain, and any misalignment of the LEKSELL frame.

An electrode is then inserted into the brain and advanced toward a selected target area. An electrical stimulus is then given through the electrode and the patient's response to it is entered into the computer. A tingling in the right hand, for instance, might be entered as -4 .3 3 1*12 p. This information is then plotted on the graphics terminal. Electrical stimulation continues at further sites until a stimulus causes the tremor or pain to disappear; the position of the electrode at this point indicates where the lesion must be made. The tissue is destroyed electrically, with no danger to the patient.

For research purposes, data is also recorded from the patient's evoked responses. That is, a tickle on the foot will produce a certain kind of neurological response. This is in fact merely the above described procedure in reverse.

In 1982, further modifications to the program began, this time concentrated on the user interface, that is, the computer operator's means of using the program. It had been found that, despite the program's working success, its use was severely restricted in that only persons very familiar with the operation, with computers and, indeed, with the particular program itself, were able to use it. As long as this situation remained, the program was in the main restricted to research use only, since the number of patients who could possibly benefit from it directly was limited by the very small number of qualified operators. It is our belief, moreover, that, wherever possible, the fruits of research ought to be transferred to the wider community. Consequently, our efforts from that time have been concentrated on the development of a transparent user interface -- a method of operating the program which will be accessible to any member of a hospital operating team, whether familiar with computers or not. This is of course a necessary step if the program is to be widely used. First, however, the program had to be transferred from the mainframe computer on which it was running; the use of a mainframe is extremely expensive, indeed, prohibitively so for any other than research purposes. Fortunately, the increasing power of microcomputers made it possible to plan the programs's transference from the mainframe to a micro -- we chose the inexpensive and widely available APPLE.

It is difficult to know where to begin in describing the changes which have been -- and which are still being -- made to this user interface. The program and its interface were designed, unhappily, in the now classic manner -- by computer scientists for computer scientists; at its beginnings, a widespread hospital use of the program was not considered. It was written in the FORTRAN computer language, which, as many of you will be aware, imposes a restrictive input format, and makes it very difficult to program a user interface which is flexible and robust. This meant that the initial program would be made to crash very easily, simply by mistyping something or entering inappropriate data. We have now completely reprogrammed the user interface -- a lengthy and extremely tedious task in FORTRAN -- so that the program is much safer and easier to use. Work is shortly to begin on rewriting the program in the flexible C language. This will make it easier to enhance the user interface further and to modify the program to deal with other neurophysiological research.

Originally, the program had no mnemonic prompts, that is, the operator was assumed to know exactly what needed to be entered. The operator is now requested, via prompts on the screen, to enter particular data in a certain form The data had previously to be specifically formatted by the operator, in a manner which gave rise to frequent input errors and sometimes caused the program to crash -- not exactly the sort of excitement needed in an operating room. The data are now entered consistently as alphabetic and numeric characters and are converted by the program into the appropriate format, so greatly reducing the likelihood of input errors. All data entered are checked by the program, and the operator is informed if anything is incorrect -- an encouraging change from the days when an incorrect entry merely resulted in a stubborn refusal to function on the program's part. Should an entry need to be corrected, editing facilities are available to the operator; all text is kept to one side of the screen so as not to interfere with the brain template shown.

Should a transmission error cause distortion or disfiguring of the picture displayed on the screen, it can be immediately redrawn, virtually at the touch of a button. Previously, a redrawing of the screen would have required all pertinent data to be input again.

A help facility is available should the operator feel in need of a reminder about the available commands or appropriate responses; in this way the need for a reference manual is avoided. The program is equipped for both novices, who are given instructions on its use, and experienced operators, who may begin straightaway without instructions.

It is our hope that the completion of work on this program's user interface will place a valuable and inexpensive tool in the hands of medical staff throughout the world. The debilitating effects of diseases such as parkinsonism and multiple sclerosis will need no introduction to our audience here. Relief of any part of this suffering and the consequent enrichment of the lives of many individuals is very certainly a worthwhile goal. It is our privilege to attempt a contribution to it.

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ACCULARM: DESIGN TO SERVICE

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ABSTRACT - This paper deals with the Accularm, a fixed interval timer, its development and utilization in a conservative remedial programme for drooling, and its progression to a treatment option recommended through the Drooling Clinic at the Ontario Crippled Children's Centre.

RÉSUMÉ - La présente communication porte sur l'Accularm, une minuterie à intervalle fixe, sur sa mise au point et son utilisation dans un programme prudent de traitement des personnes qui bavent, et sur les étapes de son application à une option de traitement recommandée par la Drooling Clinic de l'Ontario Crippled Children's Centre.

This paper deals with the Accularm, a fixed interval timer, its utilization in a research study for conservative remediation of drooling and its application as a treatment option recommended through the Drooling Clinic at the Ontario Crippled Children's Centre (OCCC).

Device

The Accularm system (Figure 1) was developed in 1981 by the Rehabilitation Engineering Department at OCCC in response to a need for cuing behavioural responses, that is, for a means of increasing swallowing frequency by prompting the subject with an auditory signal. The concept of cuing swallows follows from the work of Rapp with retarded children (2).

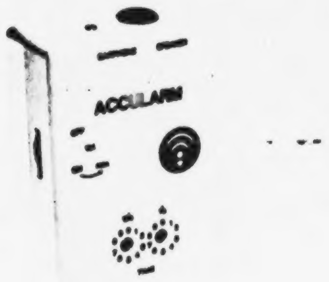

Figure 1: Accularm

The auditory signal, a chime tone, is emitted at preselected intervals (0-99 seconds) and may be received overtly or covertly (earphones). Additional features of the device include a combined on/off volume control, and the use of a 9 volt transistor battery. The Accularm measures 11 cm x 6 1/2 cm x 3 cm and weighs approximately 200 grams. This compact size and light weight enable the device to be used in either sitting, standing, walking and in various environments such as school and home, a feature which facilitates generalization of the newly acquired skill (increased swallowing frequency).

The size, shape and earphones are cosmetically attractive to children as the unit resembles a transistor radio with earphones.

Utilization in Clinical Research

An organized and concerted effort has been mounted at OCCC to address the problem of drooling. This programme in its broad scope has been described elsewhere (1). The Accularm was employed during a clinical research study in an attempt to habituate and generalize an increased frequency of swallowing. Following a 2-3 week training period in which auditory electromyographic (EMG) feedback training techniques were employed to improve coordination of the oral-motor musculature and swallowing, the child was given an Accularm to prompt swallowing. The auditory signal was usually presented at 30-40 second intervals. This device was used approximately 2 hours per day during the child's regular routines. The classroom teacher was asked to check that the device was worn at appropriate times. Most children preferred to use the earphones which did not interfere with the ability to attend to a conversational (teaching) voice. Figure 2 graphically represents the drooling rate for a S in the clinical intervention study: A_1 represents the baseline drooling rate, A_2 the post-biofeedback training rate of drooling, A_3 the post-Accularm drooling rate, and A_4 a post-one-month no-treatment baseline.

In 8 out of 12 Ss the decrease in drooling rate either was maintained or improved with the use of the Accularm as reflected in the A_3 baseline. This means that the Accularm provided a means of generalizing and increasing swallowing frequency. The slight regression in performance evidenced in the A_4 baseline highlights the need for booster sessions (regular practice) to maintain an optional performance level. Booster sessions are now possible with the Accularm which can be worn 1-2 times a week for short periods:

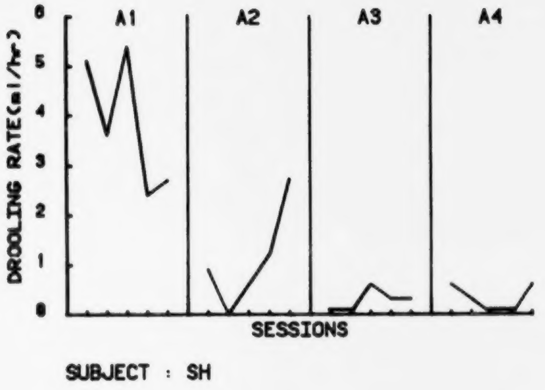

Figure 2: Baseline drooling data for S in clinical intervention study

Service

A Multidisciplinary Drool Control Clinic involving an otolaryngologist, a dentist, a speech pathologist and a physiotherapist has been created at OCCC. Various treatment options, dependent on the needs of the client are recommended: no treatment; feeding therapy; surgery; dental work; and Accularm training programme.

A behavioural modification programme utilizing the Accularm has been designed and distributed to 20 Ss through the Drool Control Clinic. The findings from this work and from the clinical research study show that the Accularm program should be recommended for the patient who possesses relatively good oral-motor skills, is able to follow directions and whose drooling problem is clinically assessed as being mild to moderate. The Accularm programme has been used with children under the supervision of parents at home, and teachers and childcare workers in schools and institutions.

Discussion

The ultimate goal of clinical research is to have positive research findings implemented in clinical service. The Accularm was designed in response to a clinical need, evaluated in a clinical research study and progressed to being recommended by a formal service clinic at the OCCC as a valid treatment option for the conservative remediation of drooling.

The Accularm can be used in research, clinical or other situations to remind or condition patients to perform a given task in the prescribed time interval.

Acknowledgements

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LOW FREQUENCY INTERFERENT MAGNETIC FIELD THERAPY DEVICE

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ABSTRACT - A new low frequency interference magnetic field-therapy device is described. The device has a carrier frequency of 500 to 1500 Hz and is amplitude modulated at frequencies varying from 0 to 100 Hz. The device is used for the treatment of inflammation and trophic diseases.

RÉSUMÉ - Un nouvel appareil thérapeutique magnétique à interférence basse fréquence est décrit. La fréquence porteuse varie de 500 à 1500 Hz et l'amplitude est modulée à des fréquences variant de 0 à 100 Hz. L'appareil est utilisé pour le traitement des inflammations et des troubles trophiques.

A principle of a new method and a device based on it is discussed. The method comprises the usage of an interferent low frequency magnetic field in the range of 0-100 Hz.

Carrier frequency, in the range of 500-1500 Hz is contolled step-by-step. Modulation frequency varies linearly and automatically in the range 0-100 Hz, for a definite period of time. Amplitude-modulated vibration is amplified by a power amplifier, where output power is controlled. Interferent low frequency magnetic field is lead to the inductors and its intensity is displayed by a magnetic field measurement system.

The block-diagram of the device is shown on Fig. 1. It contains the following blocks:

Control Unit - defines the operating mode, corresponding to the therapy kind.

Linear Generator - generates linear voltage within a definite period.

Voltage/Frequency Convertor - controlled by the Linear Generator. The conversion is completely linear. Symmetrical linear voltages, varying their frequencies within the period are lead to the convertor's output. Frequency varies in the following ranges: 1-10-1Hz, 90-100-90Hz, 1-100-1Hz and a fixed one in the range of 1-100 Hz.

Frequency Meter - controls the frequency of the symmetrical linear voltages. The main part of it is the measurement system, graduated from 0 to 100 Hz and measuring the momentary value of the voltage.

Sine-wave Voltage Former 1 - forms sine-wave voltage out of symmetrical linear voltage. The forming is carried out by a piecewise approximation and non-linear distortion factor is $k < 1{,}5\%$.

Modulator - its entry 1 is fed by a modulating sine-wave voltage from SVF1, and a carrier sine-wave voltage from SVF2 is lead to entry 2. At modulators output there is obtained an amplitude-modulated vibration in the range 0-100 Hz.

Sawtooth Generator - produces symmetrical sawtooth voltage of a fixed frequency in the range 500-1500 Hz.

Sine-wave Voltage Former 2 - forms carrier sine-wave voltage.

Amplifier - a current generator with a maximum current of 3 amps through each inductor. Output power is controlled by the Control Unit.

Inductors - concentrating the magnetic field intensity, necessary for the therapy kind.

Magnetic Field Measurement System - displays the magnetic field intensity in the inductors.

A clinical test of the device was carried out at Medical Academy, Sofia. Some groups of patients with inflammation and trophic diseases were treated. Out of 30 patients with inflammations, 23 were treated in an excellent way, 3 in a very good way, 2 in a good way and 2 patients showed no improvement.

A course of treatment, including 15 procedures, was performed with a group of 23 patients having rheumatoid arthritis. The results were the following: 17 patients no longer felt any pain, good results were achieved with 3 patients, and satisfactory results with 3 patients.

A group of 13 patients with slowly healing wounds were treated by the magnetic field as well. Best results were achieved with 10 patients, and a remarkable improvement with 3 patients.

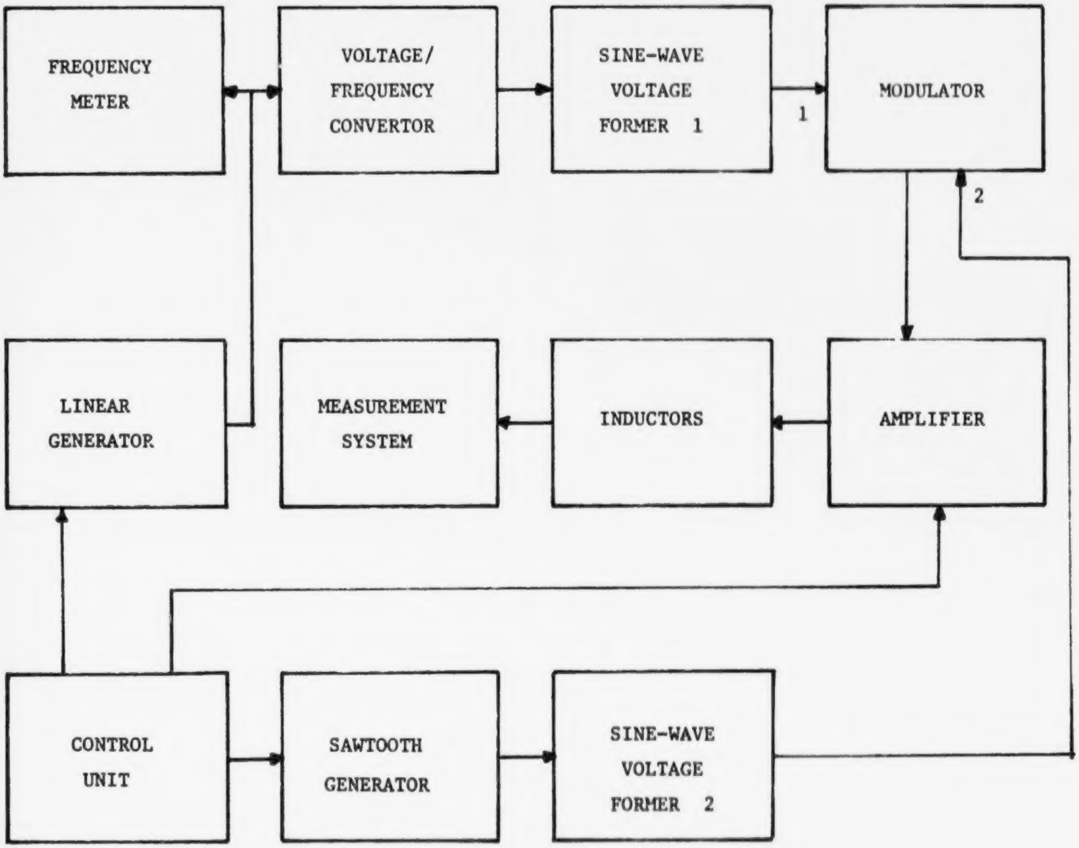
FREQUENCY METER
VOLTAGE/ FREQUENCY CONVERTOR
SINE-WAVE VOLTAGE FORMER 1
1
MODULATOR
2
LINEAR GENERATOR
MEASUREMENT SYSTEM
INDUCTORS
AMPLIFIER
CONTROL UNIT
SAWTOOTH GENERATOR
SINE-WAVE VOLTAGE FORMER 2

Fig. 1

AUDIO-BIOFEEDBACK FOR CEREBRAL PALSY HANDICAPPED PERSONS: PRELIMINARY RESULTS OF MOTION PERFORMANCE

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ABSTRACT - This paper reports the results of a preliminary study to explore the use of audio-biofeedback as an alternate sensory system to assist handicapped persons in hand motion and position. The results show significant improvement with audio-biofeedback.

RÉSUMÉ - Le présent rapport expose les résultats d'une étude préliminaire au cours de laquelle on a examiné l'utilisation de la rétroaction audio-biologique comme système sensoriel de remplacement pour aider les personnes handicapées à déplacer et à positionner leurs mains. Les résultats montrent que la rétroaction audio-biologique permet des progrès substantiels.

The long-range purpose of this study is to explore and develop the use of audio-biofeedback to improve vocational skills and independent living for cerebral palsy (and other) handicapped persons. The audio-biofeedback is used to provide an alternate sensory system to supplement existing or replace damaged sensory systems. This is in contrast to the conventional use of audio-biofeedback for relaxation training. This study will use audio-biofeedback both in training and in a "permanent assist" role.

The preliminary results were obtained from a pilot study using a group of five handicapped persons. The subjects were residents of the Timbers, an independent living facility for handicapped adults. Their ages ranged from 27 to 45. All subjects were found to have the necessary pitch discrimination needed to participate in the study.

Five simple geometrical patterns were selected for the test; vertical, horizontal, diagonal lines, and a circle. Each pattern was tested in both directions for a total of 10 basic movements. The pretest consisted of free-hand drawings of each pattern designated by a starting dot and an ending dot. The second part of the pretest consisted of each of the same movements supplemented with audio-biofeedback. The audio signal indicated the accuracy of the client's position with respect to the prescribed path. This was accomplished by the use of shaded patterns on a light table. The client moved a light sensitive transducer producing a signal which was converted to a variable-pitch sound. Following the pretest, the subjects underwent a four day training program on three of the patterns used in the pretest. Then a post-test was administered.

The test results are shown in Figure 1 as a dimensionless (score/best possible score) number and represents numerically the subject's ability to stay "on path" or close to the path for the prescribed patterns. A value of one (1) represents a perfect (always on path) score.

Figure 1 shows that with the use of audio-biofeedback the scores are nearer to one (1) as compared to the score without the use of audio-biofeedback. This shows improved performance by the supplementary use of audio-biofeedback.

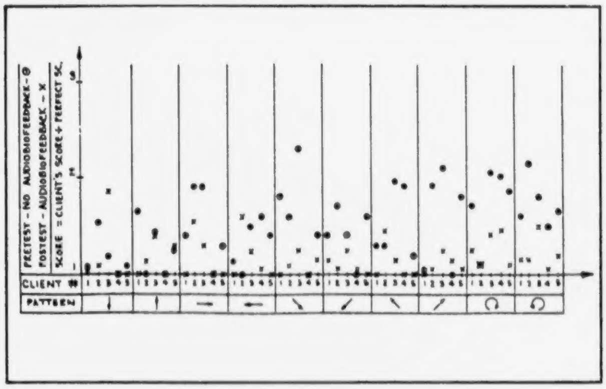

Figure 1

The results of this pilot study group are considered to be qualitative rather than quanitative. These data show that the supplementary use of audio-biofeedback shows considerable promise in assisting handicapped individuals in vocational pursuits and in independent living skills.

The preliminary data also show indications of other interesting and useful results, such as:

1. The clients show most improvement with the "most difficult" patterns.
2. The time necessary to complete each pattern was longer with the use of audio-biofeedback. However, accuracy, and not time, were emphasized in the study.

3. The training on selected patterns appeared to improve all pattern performances. This indicates the training was, at least in part, a familiarization process.

4. Certain moves appeared to be significantly more difficult. With this pilot group, the most difficult move was upward and to the left.

5. In our small pilot group there seemed to be considerable variability of performance from day-to-day with no known apparent cause. Some subjects performed worse on the post-test day than on the pretest day. However, they did perform better using audio-biofeedback than without it on either day. This would suggest that on any given day performance would be improved with the use of audio-biofeedback.

More difinitive work is planned with this system. This will include the attempt to correlate audio-biofeedback results with other sensory measurements (sight, sound, etc.) and with performance measurements from other systems. Further study regarding training and time in relation to accuracy and performance will be investigated. More importantly, the present project will move toward incorporating audio-biofeedback in vocational systems and in independent living.

SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 19

NEURAL PROSTHETICS I - STIMULATION PARAMETERS/
PROTHÈSES NEURALES I - PARAMÈTRES DE LA STIMULATION

SELECTIVE STIMULATION OF THE SCIATIC NERVE WITH MULTIPLE ELECTRODES INSIDE AN INSULATING CUFF

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ABSTRACT - Electromyography has been used in three acute dogs to demonstrate the feasibility of selectively stimulating the extensor or flexor muscles of the ankle with various electrode configurations contained within a common insulating cuff placed around the sciatic nerve.

RÉSUMÉ - On a démontré par électromyographie sur trois chiens en phase aigüe qu'il est possible de stimuler les muscles extenseurs et fléchisseurs de la cheville en entourant le nerf sciatique d'un manchon isolant contenant différentes configurations d'électrodes.

Introduction

Implanted neuromuscular stimulators have been used to correct footdrop in hemiplegic patients by activating the muscles that dorsiflex the foot through stimulation of the peroneal nerve.[1] The implanted hardware was a passive radio-frequency receiver placed in the medial thigh with a flexible lead wire extending to a cuff electrode that was wrapped around branches of the peroneal nerve just below the knee.

One problem that was observed in some of these patients was excessive inversion or eversion of the foot during dorsiflexion. This occurred despite wrapping the cuff electrode around selected branches of the peroneal nerve to produce balanced dorsiflexion of the foot during the surgical procedure. Four muscles innervated by the peroneal nerve act synergistically to dorsiflex the foot. Two of these muscles invert and adduct the foot while the other two evert and abduct while dorsiflexing the foot. It was felt that this method of correcting footdrop would be significantly enhanced if there was a way to electronically balance the contribution of these two groups of muscles post-implantation.

One method that has been proposed[2,3] is to use a single cuff wrapped around all four motor branches with an array of small electrodes positioned in different locations inside the cuff. Given a method for being able to select post-surgically any of the electrodes to be the cathode and another to be the anode, it may be possible to find a combination that would produce the desired response.

The purpose of the present study was to verify previous findings, document the results quantitatively, and investigate several different electrode configurations.

Methods and Procedure

A plastic sleeve containing seven electrodes (Figure 1) was positioned around the sciatic nerve above the bifurcation of the peroneal and posterior tibial branches in three mongrel dogs. Six of the electrodes were silver disk electrodes 1mm in diameter. Electrodes A, B and C were located on one side of the sleeve with a 3mm spacing between A and B and a 6mm spacing between B and C. Electrodes D, E and F were identically spaced on the opposite side of the sleeve. The seventh electrode was a silver band 1 mm thick and 3mm from electrodes A and D that completely encircled the nerve when the two halves of the sleeve were sutured together around the nerve.

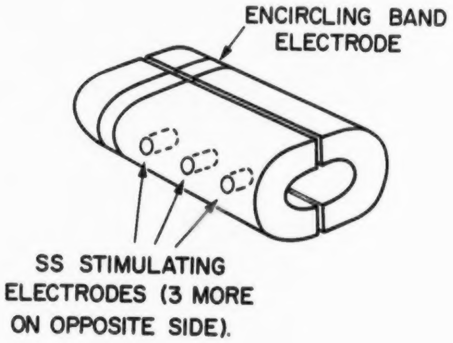
ENCIRCLING BAND ELECTRODE
SS STIMULATING ELECTRODES (3 MORE ON OPPOSITE SIDE).

Figure 1. Multielectrode Array Inside an Insulating Cuff

Wire electrodes were placed in each of four muscles to record electromyographic (EMG) activity. Two of the muscles, the gastrocnemius and soleus (ankle extensors), are innervated by the posterior tibial nerve. The other two muscles, the anterior tibialis and the peroneus longus (ankle flexors), are innervated by the peroneal nerve. EMGs were recorded from all four muscles while stimulating through a particular combination of electrodes.

In each case, the stimulus amplitude was increased to eight times the minimum motor threshold of the four muscles or until all four muscles were stimulated supramaximally. Pulse duration was fixed at 0.2 ms and the repetition rate was one pulse per second. Stimulation pulses were constant-current and monophasic.

All EMG signals were recorded differentially, amplified through Tektronix FM-122 preamplifiers and recorded on a Honeywell Visicorder. EMG responses to pulses of constant amplitude were very consistent and were either biphasic or triphasic in form. At each stimulus level, the maximum peak-to-peak measurement of the EMG was recorded.

Results

EMG versus stimulus amplitude is shown in Figure 2 for one electrode configuration. Complete separation of EMG response in the antagonistic muscle groups is seen. Stimulation through electrodes B and C that were oriented on the side of the sciatic nerve containing the peroneal branch produced maximal stimulation of the ankle flexors at a stimulus amplitude of 0.45 ma, well below 0.6 ma, the motor threshold of the ankle extensors. Using electrodes E and F on the opposite side of the nerve, the ankle extensors were maximally stimulated at an amplitude of 0.7 ma, again below the motor threshold (1.0 ma) of the antagonist muscles (not shown in Figure 2). In both of these cases, as in all others, the distal electrode was always the cathode.

Results obtained with other combinations of electrodes were excellent in two of the three dogs. In each case, two electrodes on one side of the nerve or one electrode with the encircling band as the anode were used for stimulation. In 90% of the cases tested, both of the agonist muscles reached 80% of their maximal EMG response prior to the antagonist muscles achieving 20% of their maximal EMG response.

Results were not as good in the third dog. In this animal, it was impossible to position the electrode array to obtain stimulation of the peroneal group without stimulating the tibial group. It was noted that this dog's sciatic nerve was smaller than the nerve of the other two dogs and fit very loosely in the electrode cuff.

Discussion

The effectiveness of using an array of electrodes contained in a single cuff to selectively stimulate different nerve populations inside the cuff has been demonstrated for one nerve. This nerve was specifically selected because the anatomy of the sciatic nerve lends itself to this stimulation method. The sciatic nerve is actually two nerves, the peroneal and posterior tibial, running contiguous to each other and contained in a common epineurial sheath. This made it relatively easy to orient the electrode array so that one set of electrodes was in contact with the peroneal branch and the other set was touching the posterior tibial branch. When this was done, the flexor and extensor muscles innervated by the sciatic nerve could be selectively activated by choosing certain electrode configurations. Direct electrical contact with the nerve seemed to be important. Poor results were observed in one of the dogs in which the sciatic nerve was too small to make direct contact with the opposing sets of electrodes simultaneously.

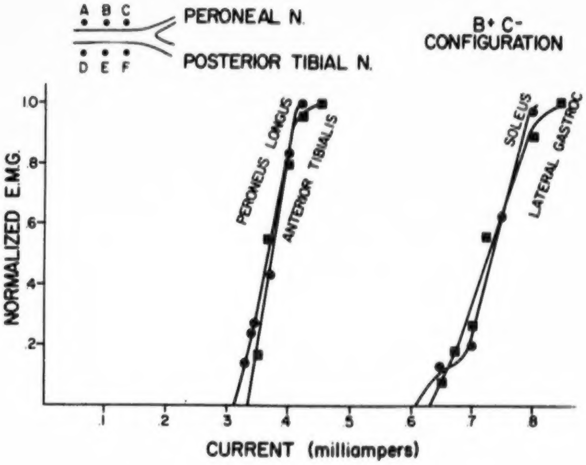

Figure 2. Peak-to-Peak Response of Four Muscles as a Function of Stimulus Amplitude

Electrode position was critical. Slight movement of the electrodes was found to degrade the results quite significantly. For the multielectrode array to work, it will likely require a large number of closely spaced electrodes covering the regions to be stimulated. After the electrode has been implanted and the wound has healed, various combinations of electrodes can be tested and the functional effect observed. The configuration yielding the best functional result would be selected. Flexible circuit technology available today coupled with electronic switching techniques can be applied to this application.

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REALIZATION OF A POLARITY CORRELATOR

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ABSTRACT - This paper describes the algorithm for implementation of a polarity correlator instrument using a microprocessor. The instrument can be used to measure muscle conduction velocity. The performance of the device compares well with other techniques.

RÉSUMÉ - Cette communication décrit l'algorithme pour la réalisation d'un instrument à corrélation de polarité utilisant un microprocesseur. L'instrument peut être utilisé pour mesurer la vitesse de conduction musculaire. Le dispositif est d'une efficacité comparable à celle d'autres techniques.

INTRODUCTION

Conduction delay measurements have a number of applications in ergonomics and rehabilitation medicine. Lindstrom, (1), has shown a decrease in the conduction velocity of the myoelectric signal during fatigue. Stalberg,(2), has noted a correlation between muscle fiber diameter and conduction velocity, and as well reported a decrease in the conduction velocity of atrophied muscle. Conduction velocity may also be affected by disease or injury of muscle fibers. This work describes an inexpensive, microprocessor based polarity correlator which provides a real time estimate of muscle conduction velocity.

BACKGROUND

Numerous techniques have been used to measure conduction delays. Lindstrom's, (1), dip frequency measurement provides an estimate of the conduction velocity from bipolar surface electrodes. Median frequency changes in the power density spectrum of the myoelectric signal have been linked to conduction changes. These techniques require analysis in the frequency domain, which often requires excessive time and/or expensive hardware.

A straight forward method of conduction velocity estimation is to obtain a sample function of the myoelectric signal from each of two recording sites separated by a known distance along the muscle fiber. The conduction velocity may then be found from the ratio of distance between electrodes and the time delay between functions. Parker and Scott, (3), demonstrated the feasibility of measuring the time delay via the cross-correlation operation. This technique was later used by Parker,(4), Naeije and Zorn,(5), and Nishizono et al,(6), in an attempt to find a reliable nonivasive estimate. The cross-correlation function estimate requires a substantial amount of numerical computation and hence there is a tradeoff between speed and cost. An alternative technique proposed by Lynn,(7), achieves real time velocity estimation through the use of digital band pass filtering and zero crossing detection on a PDP 11 minicomputer. This technique suffers from the requirement of eliminating sample function zero crossing intervals less than the delay intervals. This adds complexity to the measurement system and also makes less than full use of the signal information.

POLARITY CORRELATOR

A technique which perserves the advantages of the cross-correlation technique and overcomes the speed-cost constraint uses a polarity correlator. A digital polarity correlator passes two analog sample functions through hardware comparators and then computes a one bit digital cross-correlation function. Multi-bit A/D convertors are thus avoided and more importantly, multi-bit digital multiplication is replaced by a simple exclusive nor operation. Delay information is retained in the polarity correlation function and as shown by Bendt,(8), it can be used to measure the autocorrelation function of the original continuous signal.

The algorithm for the polarity correlation is straight forward. With reference to Figure 1, the n-bit U register stores the current and n-1 previous samples of the first sample function. A second location, D, stores the current value of the second

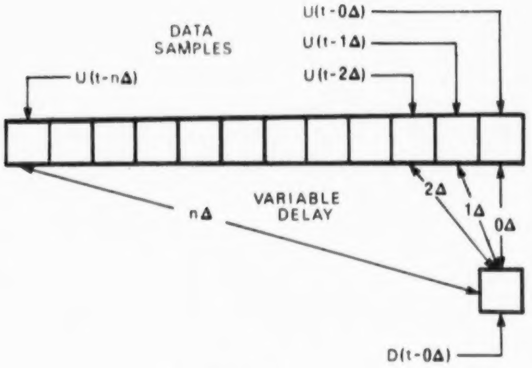

FIGURE 1

sample function. An exclusive-nor operation between D and each location of the U register generates an estimate of the polarity correlation function, $\phi_{12}(\tau)$, i.e.

$$\phi_{12}(i\Delta) = \overline{D \oplus U(i\Delta)}, \quad i = o,2,\ldots,n-1$$

where Δ is the sampling interval. If a match occurs between D and U_i a counter associated with the current value of i is incremented by one. After the n exclusive-nor operations are completed, the counts held by the n counters represent the latest update in $\phi_{12}(i\Delta)$, i = 0,1...n-1. A new data value is now shifted into the U register and into location D and the algorithm repeated. After the desired number of data values have been processed a scan of th counters for maximum count is performed. If the maximum count is at the K^{th} counter then the estimate for the delay is $K\Delta$.

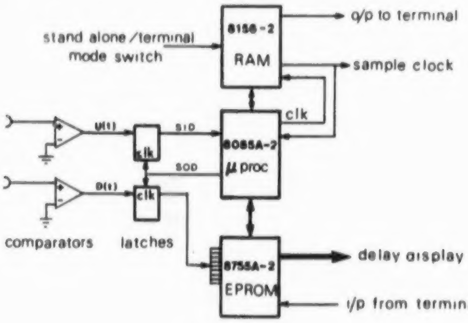

FIGURE 2

Figure 2 shows a block diagram for a real time implementation of the polarity correlation algorithm. The instrument uses the 8085A-2 microprocessor and can be used in a stand-alone mode or in conjunction with a terminal. The correlator can be run continuously, to monitor conduction velocity changes, or in a single run mode. The total number of data is selectable (up to 64000) using the terminal but set to a default value in the stand-alone mode. The sampling rate automatically adjusts to provide an optimum estimate of the conduction delay.

The device is capable of operating in real time up to a sampling rate of 5kHz. Operation above 5kHz is possible but some signal samples are not used as data in the polarity correlation algorithm and therefore the time to process N data is greater than the real time processing, $N\Delta$.

DISCUSSION

Tests and experiments demonstrate that the instrument is capable of giving conduction velocity estimates comparable to other techniques, (9). This technique has an advantage over zero crossing techniques in that it makes full use of the signal information and returns 16 values of the polarity correlation function from which the analog correlation function may be calculated. As well, the 5% instrument resolution error compares well with other techniques.

The device has other applications as well. These include; (a) monitoring conduction velocity during fatigue, (b) locating the innervation zone, and (c) measuring the autocorrelation of the myoelectric signal. The stand alone capability and portable configuration make it suitable for small clinic usage.

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ACKNOWLEDGEMENT

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EFFECTS OF STIMULUS PARAMETERS ON THE DISCRIMINABILITY OF FREQUENCY MODULATION CODES FOR ELECTROCUTANEOUS SENSORY SUBSTITUTION SYSTEMS

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ABSTRACT - To optimize the discriminability of electrocutaneous frequency modulation codes, we have compared subjects' abilities to detect frequency changes when single pulse stimuli were presented versus stimuli that consisted of bursts of pulses where the burst repetition rate was frequency modulated.

RÉSUMÉ - Pour optimiser la discriminabilité des codes à modulation de fréquence électrocutanés, nous avons comparé les aptitudes de sujets à déceler des variations de fréquence sous l'effet de stimuli comportant une seule impulsion et de stimuli composés de rafales d'impulsions dont le taux de récurrence est modulé en fréquence.

INTRODUCTION:

Electrocutaneous stimulation involves the application of coded electrical stimuli to the skin, for use as a communication channel by which surrogate or supplemental sensory information may be provided to an individual. A variety of artificial sensory systems which are based on electrocutaneous stimulation have been developed by investigators from diverse laboratories. A recent review of this field is available in reference [1]. Applications of this in our laboratory are directed toward providing feedback information about grasp force for users of myoelectric prosthetic hands and for C5 and C6 level spinal cord injured individuals who use FNS (Functional Neuromuscular Stimulation) systems to achieve functional prehension and release.

The primary design schema for our initial sensory feedback device utilizes electrodes that are implanted just under the skin in the region of the upper arm (deltoid area) where these people have normal skin sensation, and the stimuli are frequency modulated so that stronger grasp is signaled by increasingly higher stimulus repetition frequency. The use of subdermal stimulation has been found to elicit more comfortable, more distinct and more consistent sensations than is possible when more conventional surface stimulation techniques are employed [2,3] and, when combined with a suitable implantable stimulator, allows the amount of external hardware needed for the sensory feedback system to be minimized.

The discriminability of electrocutaneous codes can be enhanced by judicious selection of the stimulation parameters. One major issue in this regard for an FM code is the choice of using single pulses which are freq. modulated or of using bursts of pulses in which case the repetition rate of the bursts of pulses forms the basis of the FM code. A priori, a single pulse FM code requires less circuitry to implement and is energy efficient in terms of the power actually expended in eliciting sensations from the skin. FM codes based on bursts of high freq., however, are reported by our subjects to be more comfortable in that they produce more pleasant skin sensations. In order to decide which code format to use we investigated another important aspect of the FM code which is the relative ease and accuracy with which the users can distinguish changes in freq. This paper describes the preliminary findings of that investigation. Initially, two situations were compared: an FM code in which single pulses were utilized (SP) and an FM code in which bursts of fixed duration (FBD) were employed. The results of these studies led to the development of a hybrid code in which the duration of the bursts was made to vary in accordance with the burst repetition freq. that was to be presented. This hybrid or variable burst duration code (VBD) was demonstrated to provide superior discriminability in comparison to the SP or FBD codes.

MATERIALS AND METHODS:

Electrodes - The subdermal electrodes consist of tightly coiled fine stainless steel wire, similar to those developed by Caldwell and Reswick [4]. With the aid of a 19 guage hypodermic needle, each electrode is inserted percutaneously and then the needle is withdrawn leaving the electrode to remain in place just below the surface of the skin. An adhesive backed, molded rubber cap is fixed to the skin at the site of entrance of the wires to provide protection and convenient electrical connection. The electrodes may be allowed to remain in place for many months while studies are being performed. Afterwards they are easily removed by simply pulling them out. The electrodes are used monopolarly, connected cathodally and have an active tip of 10mm length. A large moistened cloth covered pad (25 sq cm) applied over the skin at the shoulder is used as a remote anodal electrode to provide a diffuse return pathway for the current.

Stimuli - Stimuli consisted of single or bursts of monophasic, capacitively coupled, 50usec, constant current pulses. Burst stimuli consisted of 1 KHz trains of from 2 to 6 pulses and the burst repetition freq. was limited from 2 - 55 Hz.

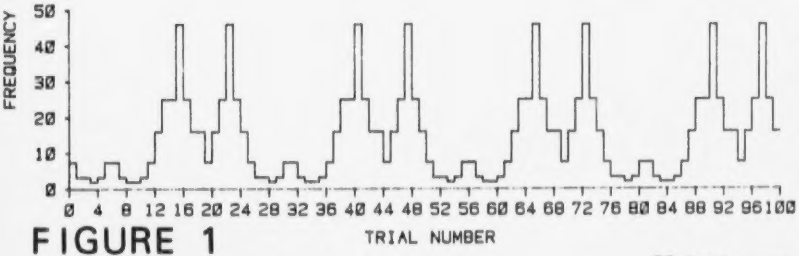

FIGURE 1

Discriminability test for FM codes - A psychophysical task was designed to test each subject's ability to discriminate step-wise changes in stimulus freq. over a period of several minutes. For each subject, prior testing using an adaptation of the "Dual Staircase Method" [2] established a personal table that specified successive Just Noticeable Differences (JNDs) of freq. Employing this information, each freq. change that was used for the discrimination task was selected to differ from the preceding stimulus by 2 JNDs.

A string of freq. changes was stored in a computer file for each subject so that it could be presented repeatedly. Each subject had his own unique file in terms of the actual freqs. used, but the sequence of changes regarding their relative directions (i.e. increases or decreases) and the various display times were consistent for all subjects. An example "Task File" is shown graphically in Figure 1. This sequence of freq. changes was presented to the subject who was required to depress an electrical switch each time that a freq. transition was detected. To discourage guessing and habituated responding three different display times were utilized at all freq. levels throughout the test, and 20% of the 100 total trials consisted of "no change trials" in which no freq. transition occurred.

Each test run (presentation of 100 trials) lasted 4 min. and consisted of identical 1 min. quarters. There were five different increases in freq. as well as five complementary decreases in freq. in the task, and each of these ten events occurred 8 times during each experimental run. Ten experimental runs were given for each test session and each run was separated by a 4 min. rest interval during which the stimulus was turned off. The results of the ten runs were superimposed to emphasize trends and to reduce variability. This averaging procedure was extended to include data from identical experiments taken during two or more test sessions.

RESULTS:

Similar results were obtained from each of the four subjects who were tested. Figure 2 shows a comparison of the performance of one of the subjects on the freq. discrimination task when each of the three coding schemes (SP, FBD and VBD) was employed. All subjects were well trained on the task using each of the codes before the data shown were acquired. Two or three sets of 10 runs each were performed with each code, and these data were taken during test sessions that were spaced over several days.

Subjects were unaware of the particular pulse code being presented or that comparisons of performance would later be made. The code types used in successive test sessions were intermixed to offset potential artifacts that might be caused by serial ordering during data acquisition. The histograms (Fig. 2) depict the % correct responses from each of the 20 test runs associated with each code type. The subject's performance was also measured using a visual display (flashing LED). For the example data shown in Fig. 2 the mean % correct responses for the SP, FBD, VBD and VISUAL displays were 42, 41, 53 and 79 respectively. For this subject the use of the VBD code afforded a 26 % improvement in his ability to detect changes in freq. ($P < .01$). The improvement in performance gained collectively by the four subjects for the VBD code over the SP and FBD code was 30 %.

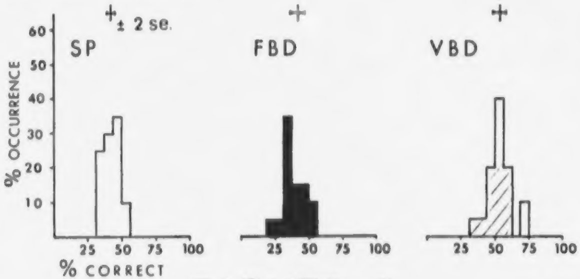

FIGURE 2

An examination of the recognition rate of each of the ten possible freq. transitions revealed that the most common errors with the use of the SP code were different from those with the FBD code. The SP code was readily discriminated for high freq. transitions but relatively poorly discriminated for low freq. transitions. For the FBD code opposite results applied. With the FBD code subjects performed well for low freq. transitions but had difficulty at high freqs. The VBD code affords more uniform performance over the total freq. range.

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EVALUATION OF CUTANEOUS SENSATION IN MYELODYSPLASTIC CHILDREN USING ELECTRICAL STIMULATION

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ABSTRACT - Cutaneous electrical stimulation (CES) was compared to standard neurological examination for detecting the presence of sensation in myelodysplastic children. Both methods agreed for normal or absent sensation, while partial sensory deficits and sensation in infants were frequently only detected by CES.

RESUME - Deux méthodes pour déceler le présence de sensation chez les enfants myelodysplatiques ont été comparées: les stimulations éléctriques cutanées et l'examen neurologique standard. Les deux méthodes se sont avérées efficace à établir la présence ou l'absence de sensation. Cependant seul les stimulations éléctriques décelaient les sensoriels partiels.

Accurate information concerning the sensory status of the extremities is difficult to obtain in patients with spinal cord injuries. Yet defining the remaining sensory capacities is necessary to plan the appropriate treatment strategies. This problem is particularly acute in children too young to cooperate with the examiner(1). This study compared a novel method of detecting cutaneous sensation, specifically, cutaneous electrical stimulation (CES) with the standard neurological examination (SNE) as a means to gain this information.

The study was conducted at the Shriner's Hospital in Montreal, Québec. All myelodysplastic children attending the hospital were considered if they fulfilled the following criteria: (i) an open myelomeningocele, (ii) situated caudal to and including the second lumbar vertebra and (iii) had parental consent.

The 28 children studied had a mean age of 8.8 y, (median 8.0 y) with a range of 8 mo. to 17 y. Seventeen were male, 11 female. As a preliminary step, the reliability of CES was examined. A group of 5 children within the same age range as the test population was evaluated. Without exception the CES confirmed the previously known diagnosis. To establish the reproducibility of the results of CES, tests were repeated on two consecutive days on 3 patients. Perfect correlation was demonstrated for 17 of the 18 areas tested.

In the group of 22 that received both the SNE and CES, the SNE was performed by the resident doctor or the staff physiotherapists, the CES was administered by the first author. The order of the tests was constrained by the availability of the testers. Each examiner was blind to the other's results.

The SNE consisted of three stimuli; light touch applied by a cotton wisp, pain by a pin prick and cold by a quick application of an ice cube. Each stimulus was applied 3 times to each area of the right and left foot. Six catch trials (i.e., occasions in which no stimulus was given) were interspersed with the stimuli. A random order of stimulus and no stimulus events was applied to each area.

For the CES, the child sat on an elevated mat with his feet shielded from view by a table. The skin on the area tested was washed and two small T22P electrodes were attached to each stimulus site. The CES used a 50 Hz full-wave rectified electric current generating 100 stimuli/s. The manufacturer reported that the stimulus was designed to activate cutaneous receptors maximally (2). For the first trial the current intensity was raised gradually. This avoided any discomfort to the patient as well as ensured the continuing cooperation of the child. Generally, the sensations were described as vibration, heat, or itching. If no response was elicited in the first trial, the intensity was raised to maximum quickly to avoid the possibility that the afferent fibres had adapted to the slowly increasing stimulus intensity.

Another 6 subjects too young to comply with the instructions of the SNE examination were evaluated by the CES method only. Typically the child was held in the mother's arm. The stimulus current was slowly raised. Either an orienting response or a stimulus-induced vocalization was accepted as a positive response. The child was distracted before the current was raised again. The stimulus intensity was carefully maintained at innocuous levels; no pain induced vocalizations were observed.

Each examiner recorded correct or incorrect responses. Percentage correct scores were calculated from these. In the CES, the behavioural response was accepted only if it followed immediately after the stimulus and indicated an awareness of the stimulus. Any lower extremity movement that might have been a reflex withdrawal without a conscious perceptual response was not accepted since it might have been of spinal origin from regions below the level of the defect.

In both tests, sensation was considered to be present when the subjects performed at a level of 75% or greater. The cutoff score of 75% was chosen instead of a higher value because a higher criterion would increase the risk of classifying some areas as lacking sensation when in fact it was present.

The results of the CES testing from 132 sites in these 22 subjects showed that sensation was present in 83 sites where the subjects responsed correctly 100% of the time. In 43 other test sites the subjects never detected the stimulus and scored 0% correct responses. Only in 6 cases was the result less clear, being some value other than 0% or 100%. Using a 75% criterion level, four were judged to have sensation and 2 to have none. Thus, the CES gave clear results in all but 6 areas. The distribution of the scores of the SNE tests was more scattered; only 37 sites were scored 100% while 32 were unequivocally devoid of sensation. The remaining 63 sites produced scores ranging between 20% and 100%, with 22 having scores above the 75% criterion but not reaching 90%. Clearly the SNE scores had more variation and were more difficult to interpret.

In ten children, the SNE and CES tests were in complete agreement, one test measured sensation as effectively as the other, consequently these patients were not considered further.

The remaining 12 children (72 test sites) displayed less consistent results and obtained SNE scores ranging between 22% and 100%. Children often responded inaccurately to some of the catch trials. In these patients the CES test indicated sensation present at 57 of the 72 stimulus sites and absent in 15, while SNE indicated sensation present at 29 of 72 sites and absent in 43. A site-by-site examination of these results revealed that the results from SNE and CES were in agreement at 40 sites, with sensation present in 27 areas and absent in 13 areas. At the other sites CES and SNE results did not agree. The pattern of discrepancies was informative; only twice did the SNE indicate sensation present when the CES indicated its absence, whereas 30 times the CES detected sensation that the SNE test had missed, suggesting that CES frequently detected cutaneous sensibility in the areas where the SNE did not.

In the group of 6 babies tested only with CES the resuts were equivocable; 21 of 36 areas had sensation (with 100% score), 15 areas none (with a 0% score).

The results presented suggest that CES will detect cutaneous sensation more effectively than SNE in patients having partially denervated lower limbs as a result of myelomeningocele. The implication is that CES provides a more reliable indicator of an avenue for sensory appreciation. Further, the tests can be used in patients too young to be examined by the SNE.

There are several possible reasons for the greater effectiveness of CES. The SNE method measures light touch, pain and cold appreciation. Each stimulus is designed to excite preferentially a different class of receptors and afferent fibers. The sensory apparatus and neural pathways for each class of sensory input must be intact for these stimuli to be perceived. In contrast, CES provides an electrical stimulus which is able to elicit responses from any of the afferent fibers serving the skin. The electrical stimuli simultaneously activate relatively large numbers of afferent fibres (2) including the small C fibres subserving high threshold inputs. Since CES causes a synchronous volley of afferent activity it minimizes spinal inhibitory mechanisms and increases the possibility of trans-synaptic transmission of afferent information (3). Thus, it is probably a maximally effective stimulus. In applying the CES stimulus, there is an initial sensation of prickling fibrillation. This suggests that the small C fibres are being stimulated preferentially.

Precise and repeatable measurements of cutaneous sensation are difficult to attain because sensory appreciation is influenced by many environmental and psychological factors (4). SNE is more readily influenced by these. It appears that children and adults believe that the correct answer is the one that indicates when the input is applied rather than when it is felt. The subject is alert to any cues in the testing environment that indicate the time of stimulus application. The SNE is generally used without including controls for extraneous cues or guessing, but it can be improved by using a paradigm with no-stimulus catch trials and calculating the percentage correct scores as was done in this study (4). Nevertheless, CES was less sensitive to these factors. The possibility of guessing did exist but this was less likely as the examiner applied the stimulus at random time intervals and only if the child was engrossed in another activity.

One problem with CES was that the threshold to electrical inputs could vary depending on the attention of the child and his involvement in activity. This was not a serious problem since the maximum current seemed high enough to draw the child's attention if the sensory path was intact. However, measurements of sensory thresholds would clearly require another experimental design.

In summary, the CES examination provides a more reliable method to detect the existence of pathways for cutaneous sensation. It can be applied to babies and children too young to cooperate with the SNE. As a result, the CES procedure may be useful clinically for planning appropriate rehabilitation procedures for children with severe sensory deficits.

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IMPROVED SYNTHETIC WALKING IN THE PARAPLEGIC PATIENT USING IMPLANTED ELECTRODES

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ABSTRACT - Improvements in synthetic walking using percutaneous intramuscular electrodes under computer control have been made by implanting additional muscles. The inclusion of plantar and dorsiflexors has corrected footdrop and has assisted in weight transfer. Implantation of hip muscles for hip extension has improved posture and increased the patients' security.

RÉSUMÉ - On a réussi à améliorer la marche artificielle commandée par des électrodes percutanées intramusculaires grâce à l'implantation de muscles additionnels. L'inclusion de muscles pour la flexion plantaire et la dorsiflexion a corrigé le pied tombant et a aidé le transfert de poids. L'implantation de muscles de la hanche pour l'extension de la hanche a amélioré la posture et accru la sécurité du malade.

INTRODUCTION

Mobility for the patient with paraplegia remains a serious problem even with utilization of the most modern rehabilitation techniques. Access is limited, presenting major vocational and social obstacles. Recent reports from this laboratory and others have demonstrated reciprocal walking utilizing electrical stimulation in the paraplegic patient (1,2,3,4). Demonstration of functional walking - walking useful in the activities of daily living - has yet to be demonstrated by any laboratory.

The purpose of this communication is to report our progress toward the goal of functional walking. We have approached the goal through improved motor function, improved control, improved dependability, reduced fatigue and reduced energy consumption.

MATERIALS AND METHODS

Eight paraplegic patients were studied. Their injury levels ranged from T4 to T11 and their ages from 21 to 33 years. Initiation in the program ranged from July 1982 to January 1984 and time post injury ranged from two months to five years. Previously described percutaneous intramuscular electrodes and implantation techniques were used (5,6). Stimulation was done with a 32-channel, microprocessor-controlled stimulator which was produced in our laboratory (7).

One of the approaches to improving gait involved adding muscles for foot control to the already implanted muscles which controlled knee and hip action. Initially an attempt was made with our usual medial-thigh insertion site for electrodes to stimulate the foot dorsi- and plantar flexors. While possible, this proved to be technically difficult and a new site just below the medial tibial flair was chosen. The dorsiflexion electrodes passed between the tibia and fibula to enter the appropriate muscles. The site has been well tolerated in the five patients that have been implanted. Strong reproducible dorsi- and plantar flexion has been achieved in all patients attempted.

Implantation of hip muscles for hip extension presented special problems. Many cadaver dissections were done to attain an adequate understanding of the usual anatomical variation present in the innervation of these muscles. Intraoperative ultrasound was explored as a method for improving the technique and remains promising. We are currently continuing to use the medial thigh implantation site for all hip muscles. For abductors, hamstrings, and gluteus maximus the patient was placed in a prone position with the hip on the side to be implanted held in full extension by an assistant. A surgical prep was done and the best sites for implantation were determined using a 26 gauge probe. The abductors were generally posterior and medial to the proximal tip of the greater trochanter; the gluteus maximus, proximal and lateral to the ischial tuberosity; and the hamstrings midway between the knee and hip and slightly lateral to the center of the thigh. After a two-week healing period, the implanted muscles were exercised for one hour per day. Strength was assessed using the Cybex dynamometer. Strong abduction was more difficult to achieve than hip extension.

Gait analysis was done through direct observation, through study of film and videotapes, and through the use of twin Advanced Mechanical Technology, Inc. force plates. Three kinds of exercise were included in a program designed to develop improved muscle strength and aerobic capacity. Swing-to and swing-through walking using conentional bracing was done three times a week. One hour per day of electrical exercise while supine and one hour three times per week of electrical walking completed the exercise program. Assessment of physical condition was done using a mounted Monark bicycle ergometer and blood presure and heart rate measurements.

RESULTS

Implantation of the ankle dorsiflexors removed the need for an ankle-foot othosis (figure 1). Foot drop was easily corrected and hip flexion improved, resulting in a much smoother gait. Addition of active plantar flexion changed the entire walking pattern. Prior to this the patient moved the walker, adjusted his upper body to unweight the swing leg and then activated the swing. The active plantar flexion was used to push the center of mass over to unweight the swing leg and then the swing immediately followed. Force plate measurements indicated that the patients were taking between 30% and 60% of their body weight on their arms with the old technique during gait initiation. Force plate evaluation of the new gate style is underway.

Active control of the hip muscles resulted in a much straighter posture with reduction of the lumbar lordosis characteristic of the paraplegic standing posture. Abductor lurching was reduced. Active pelvic thrust was possible. Subjectively, the patients stated that they felt more secure and stable.

The patients reduced their heart rate for equivalent work loads by about 15% and had the same reduction in resting heart rate. Trunk control was improved though exercise of the latissimus dorsi muscles. Five of the eight patients have been able to walk in parallel bars; three of them are also able to walk with a standard walker. The range of distance is 5 M to 15 M.

System reliability was improved by providing a backup electrode for each function and replacing the electrodes as they failed. The failure rate was approximately 1% per month. Work has continued on the implantable version of the system which will not require any percutaneous wires.

DISCUSSION

This study represents an effort to initiate the transformation of our previously demonstrated synthetic walking system into a more functional technique. Analysis of the currently used stimulation patterns reveals that there is much more similarity to gait initiation as described by Mann, et al (8) than to steady state walking. Addition of the foot and hip muscles as described above has allowed us to more nearly simulate gait initiation as it occurs in the normal and has resulted in improved function. The addition of some aspects of closed-loop control should further improve function and may allow actual steady state walking as opposed to individual initiation of each stride. Device dependability should be greatly improved with application of the implantable stimulator currently being developed. These changes should allow major progress toward truly functional walking.

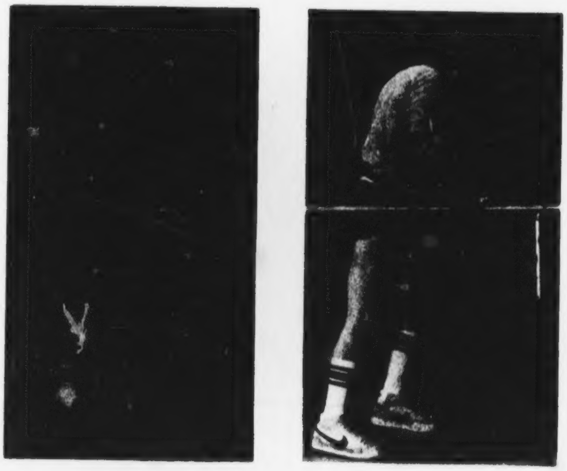

Figure 1

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SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 20

COMPUTERS III - OCULAR AND VOCAL INTERFACES/
ORDINATEURS III - INTERFACES VISUELLES ET VOCALES

TOWARDS PRACTICAL VOICE CONTROLLED AIDS

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ABSTRACT - This paper presents some of the factors which must be considered when using speech recognition systems. A threaded language with simple English commands will be described.

RÉSUMÉ - Cette communication présente certains des facteurs dont il faut tenir compte lorsqu'on utilise des systèmes de reconnaissance de la parole. On décrit un langage constitué de commandements simples en anglais.

Introduction

In the next five to ten years we can expect a wide range of voice input sub-systems will become available. These will range in performance (and therefore in cost) from simple, user specific, limited vocabulary discrete word recognizers through to any user, continuous speech recognizers. The bottom end (in technological terms) of this range is with us now, for example as products from Interstate Electronics (USA) and Infovox (Sweden). It is this author's contention that successfully using voice input as part of an aid will involve a great deal more than just unpacking a recognition unit and plugging it in. This paper explores these extra considerations. In order to make it less abstract a scenario will be used of a voice operated manipulator attached to the bed of a severely physically handicapped person. The conclusions, however, are applicable to other situations.

The limitations of simple voice input devices themselves

Potential users of voice controlled aids will be directed towards the simpler type of system by cost considerations. However, even if cost were not a factor, a good argument could be advanced for deliberately using a user specific system as it is desirable for a user to have sole control of their aid. An aid that responded indiscriminently to any voice would be impractical for use in a crowded environment, even assuming benign motivation on the part of all concerned.

A simple voice input system will only recognize a limited number of words, currently rarely more than one hundred with present low cost systems. This is mainly due to the time taken to test an input word against all the reference words one at a time. It is quite possible to test a large number of reference words but the time of response becomes too slow for realistic use. So one is faced with the problem of attempting to control an analogue world with a limited digital vocabulary. This is not so different from control using a conventional keyboard. However, unlike when using a conventional keyboard, it is possible to supplement the discrete vocal input with an analogue input. This can be achieved by means of whistling or humming. The frequency of this extra input can provide the information needed to control the rate at which the digitally selected operation takes place. This might be considered as the vocal equivalent of a one axis joy stick. Action would cease if the tone stopped altogether, but recommence as soon as the tone returned. Such an arrangement is more fail-safe than one in which action only stops on receipt of a command. Voice control during a feeding operation poses obvious problems, and these, along with other safety aspects will need very careful attention.

The problem of limited vocabulary

It is appropriate that the user should be given access to fairly primitive control movements in order that they are able to respond to new situations as they arise. However, these 'low level' commands by themselves will not be convenient for describing complex but repetitive movements. Once one of these 'high level' movements has been defined it is desirable that it be possible to cause it to be re-enacted with just a single command. The number of command words would obviously become very large if one tried to be ready for all possible contingencies at one time. Realistically the number of sensible options in any given situation is far smaller than the sum of all options for all situations, and so it should be acceptable to have a dynamic command set with new ones being learned as needed and forgotten when their utility is over. It may be possible to separate the needed words into different vocabularies for different situations, for example one for feeding, another for reading etc. In this case the ability to always have a low level command set available and to switch between supplementary sets of high level commands as appropriate would be highly desirable. In this way a large total number of commands could be maintained although not all of them would be available at any one time.

It is possible to provide such in field reprogrammability and context sensitive command set selection no matter what language one uses, but some languages lend themselves to the task more than others. One type of language that is obviously well suited to this type of task is a threaded language. The most commonly available example of such a type of language is Forth.

The advantages of threaded languages

Threaded languages differ from conventional interpreted languages (such as Basic) or compiled languages (such as Pascal). They consist of a simple compiler that will compile new code and add it to existing code as well as a small and fast interpreter to execute the code. Programs consist of routines each of which are named by a single word and which are constructed out of pre-existing simpler words. New words can be added and old words forgotten at any time. Words are grouped together into vocabularies which can be switched in or out of use at will. Simply issuing the name of a routine causes that routine to execute. Execution can be fast, fast enough for real time operation of a mechanical device such as an artificial arm in a closed loop mode.

The preceding paragraph lists some of the features of threaded languages which make them suitable for use with voice controlled aids. There are disadvantages too, of course. These will in general differ from threaded language to threaded language. Taking Forth as an example, since it is the most commonly available threaded language, two obvious difficulties become apparent. The first arises from the internal structure of the dictionaries that hold the vocabularies. This has the result that, when a word is forgotten, all words learned subsequently to that word are also forgotten. This is not desirable in our scenario. Fortunately, it is quite possible to write a threaded language in which the word headers are kept in a separate list from the word definitions, although such an implementation is not strictly Forth. With such a slight revision to the internal structure it is possible to arrange that, when a word is forgotten, only other words that depend on the now deleted word are also forgotten. Words that are unrelated to the deleted word are not touched.

The second program relates to the symbols used to write Forth programs. Originally as many 'words' as possible were shortened to single characters to speed use of the language via slow electromechanical printing terminals. Thus ':', ';', '.', ',', '!' and '@' (to mention but a few) all have special meanings. This has the effect of making written Forth nigh on incomprehensible to anyone but a Forth guru. However these 'names' can be changed at will to something more obviously meaningful, although again the language should no longer be called Forth.

It is quite probable that no standard threaded language will prove to be totally suitable and a custom threaded language will need to be written for use in voice input situations. A project to produce such a threaded language with simple english commands and in a form suitable for use by the noncomputer literate physically handicapped is currently underway at R.M.I.T. Fortunately one further advantage of threaded languages are that they are highly modular, easily portable and fairly easy to adapt when compared to a conventional interpretive language such as Basic.

Ensuring that words are not forgotten accidentally

Once a user has the ability to instruct their own aid and to keep it up to date with their requirements, the problem arises of the security of their work. It would be hard to imagine any greater disincentive to using the aid than to have it periodically and unpredictably suffer from amnesia. Disc storage could be organised to meet the requirement for fast access non-volatile reusable storage but would have disadvantages in terms of cost, environmental needs and long term reliability. Battery backed up CMOS ram has no moving parts, and, provided a suitable sized rechargeable battery is provided, could offer almost indefinite long term storage. Another solution worthy of close attention is to use EEPROM. At present the cost of these devices is high but they are the first non-volatile semiconductor ram. Providing the writing rate is low (as it would be if they were used to save new word definitions) their expected useful life is to all intents and purposes infinite.

The choice of vocabulary

One of the advantages of voice input as far as some handicapped users will be concerned is the fact that the input need not be in the form of conventional words. The only requirement is that the user be able to generate a set of acoustically discrete utterances and be able to reproduce them on demand. Very short and similar sounds (for example the letters 'b', 'd', 'e', 'p' and 't') are too hard to distinguish reliably at present. Long utterances are hard to use unless the recogniser can accommodate differences in speech rate (non-linear time mapping between the unknown and reference utterances). Given that fatigue and other non-controllable factors will inevitably lead to speech rate differences during the course of a day, recognisers that only perform linear mapping are likely to prove useless under practical conditions.

Acoustically similar words, even if of suitable length, will cause problems (for example 'moon' and 'noon') and considerable care will need to be exercised to ensure that word sets chosen are sufficiently distinct. How the system should respond to receipt of an unknown word (or stray sound) will depend on context. At times it will be desirable for all action to immediately cease while the user is asked to repeat. At other times (when there is no danger to the user or their environment) the continuation of the current action until a known command is received may well be the most realistic policy.

No matter how unrecognised words are handled the number of these words must be kept low, by the use of noise canceling microphones and adaptive amplitude threshold levels for example. A high level of non-recognition or, worse still, misrecognition will only result in severe user frustration and, ultimately, to system rejection.

Conclusion

For the near future affordable voice input devices for use in aids for the handicapped will be of the user specific, limited vocabulary type. This will force designs to often include at least some facility for the user to update the performance in the field. This in turn will require the use of languages designed to support infield instruction modification and require that the contribution of the user in dynamically customizing the aid is protected. The word set(s) used must be chosen so that recognition scores are high and user frustration is kept low.

Unless adequate consideration is given to these factors users will reject voice input once the initial novelty has worn off. Without user acceptance the most dedicated work in development is wasted. This would be sad as voice input would appear to have much to give many users, offering, as it does, a more natural type of user interface, largely independent of the user's physical dexterity and free from the awkwardness and slow speed of key entry.

AN EYE GAZE CONTROLLED KEYBOARD

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ABSTRACT - Sentient Systems Technology, Inc. (SST) has developed a non-contact, direct selection based, eye gaze controlled keyboard - the EyeTyper. Keyboard selections may be made rapidly and extended use is non-fatiguing. Print, speech, and computer keyboard emulation are available as options.

RÉSUMÉ - Sentient Systems Technology, Inc. (SST) a mis au point un clavier sans contact à sélection directe commandé par le regard, l'EyeTyper. Les choix sur le clavier peuvent se faire rapidement et l'utilisation prolongée de l'appareil ne cause pas de fatigue. L'appareil peut être relié à une imprimante, un synthétiseur de parole et à un clavier d'ordinateur.

Essential to the human condition is the ability to communicate. Some physical handicaps are debilitating because they impair communication for both social and vocational purposes. Even where adaptive aids may be used to augment the communicative abilities of the physically handicapped, social communication is hampered by the slow rate at which messages are typically produced. This requires patience on the part of the listener that all may not tolerate. Communication for vocational purposes may be uneconomically slow thereby limiting the independence of an otherwise competent individual.

It is desirable for an augmentative communication aid to allow for direct selection of words and letters. Typical, however, of the aids designed for those with severe physical impairments, are scanners that require a user to wait for the device to present the desired word or letter from a list. This process is inherently slower than direct selection, but can be accomplished by a simple switch closure. Often physical infirmities prevent overt movements more elaborate than switch closure.

Many people who do not have sufficient voluntary control of their bodies to use more than simple, single switch scanners, retain their ability to view their environment. For these individuals, direct selection communication based on their eye movements would be most desirable.

A communication aid based on eye movements is potentially the most rapid and least fatiguing device available to the non-vocal. Historically, eye movement measuring instruments developed for clinical use have depended upon electrodes affixed to a patient's face or photosensors mounted on frames around a patient's eyes. Electrodes are undesirable both on aesthetic considerations and from the standpoint of safety. Photosensors mounted near the eyes may likewise be a hazard and furthermore require frequent realignment. Remote sensors of eye movements that avoid these problems have been developed for military, advertising, and academic research applications. These remote "oculometers", based on the infrared refectance of the eye, are sensitive and costly instruments. Any communication aid based on them would cost tens of thousands of dollars.

Sentient Systems Technology, Inc. (SST) has developed a non-contact, direct selection based, eye gaze controlled keyboard - the EyeTyper. It is optimized for ease of use, reliability, and safety. When a user, sitting 15 to 20 inches from the EyeTyper, gazes at the letters and words on the display, the location of his gaze is automatically determined and the center of that key is illuminated. If the user wishes to select that key, he lets his gaze dwell there a moment longer. A flash indicates that the EyeTyper has accepted the entry. If the user does not wish to select the key he moves his gaze. The fixation can be varied from $\frac{1}{2}$ second to 3 seconds. This feature was included because the $\frac{1}{2}$ second response time is too fast for first time users and some clinical conditions. Users can control the EyeTyper response time to suit their abilities.

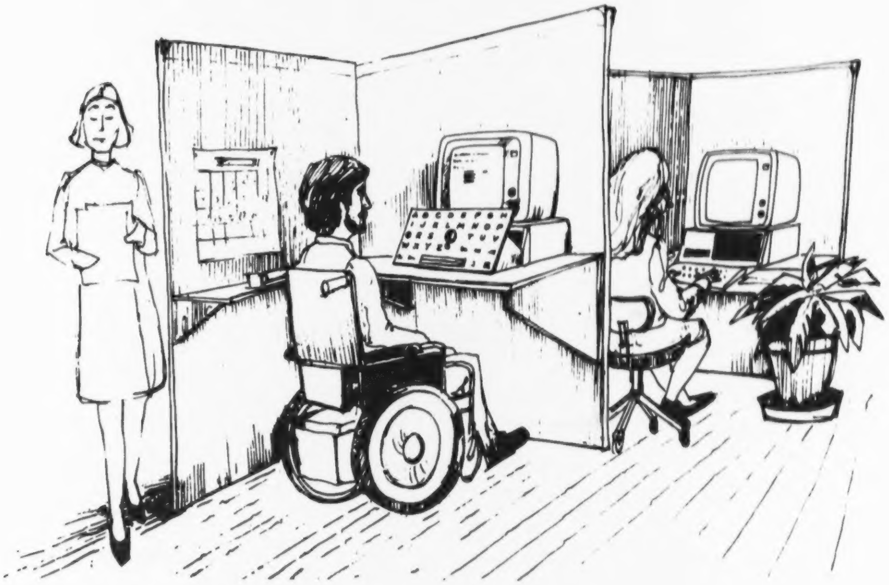
Once a word or character is accepted by the EyeTyper, it appears on the 2 line by 40 character liquid crystal display which is located below the bottom row of characters on the "keyboard". The contents of this diplay buffer my be used in many ways. It can be used directly for communication purposes or, via the EyeTyper's serial RS-232 ASCII output port, may go to many external devices such as printers, environmental control units, and keyboard emulators. The Trace Center keyboard emulation scheme is fully supported, allowing the eye gaze "keyboard" to serve as the keyboard for many personal computers, such as the IBM-PC and the Apple)(e, totally transparent to the host computer's software. An optional speech output capability is also available.

Physically, the EyeTyper is 18 inches wide, 9 inches high, 6 inches deep, and can be powered by a conventional motorized wheelchair battery or from a wall outlet. The "keyboard" display is a sloping panel 18 inches by 10 inches, inclined for user comfort when placed in the position of a conventional keyboard. Within the device, is a small infrared source, a video camera, microprocessors and cumstom video processing hardware.

The characters of the keyboard are arranged in a checkerboard fashion on the "keyboard" display. For institutional evaluations and comparisons with other more conventional aids, the EyeTyper's advanced output features may be controlled by an external mechanical switch with the keyboard display operated as a conventional scanner.

In summary, the EyeTyper is a safe and convenient direct selection communication aid based on eye gaze. No physical contact with the user is necessary. Keyboard selections may be made rapidly and extended use is non-fatiguing. A dynamic display and a RS-232 serial output are standard. Print, speech, and computer keyboard emulation are available as options. The EyeTyper should find use not only as a communication aid for the non-vocal, but also as a means of enhancing computer control for quadriplegics and other vocal physically handicapped persons.

The design of this device was developed in cooperation with the Trace Center at the University of Wisconsin-Madison. This work was partially sponsored by the State of Pennsylvania's Ben Franklin Partnership Program.



AN EYE TRANSDUCER FOR ACTUATING A TYPEWRITER

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ABSTRACT - This paper describes the design and operating features of a low cost optically activated eye transducer to be used by people with very severe communications difficulties for generating messages via a printer.

RÉSUMÉ - Cet article présente la conception et les caractéristiques de fonctionnement d'un transducteur optique qui a pour but d'aider les personnes handicapées au niveau de la parole, à communiquer à l'aide de messages transferrés de l'oeil à une imprimante.

INTRODUCTION

Certain people are so severely handicapped that the only reliable means of communication remaining to them are the eyes, which can serve not only as a means to receive but also to send information. This paper outlines progress made with a device designed to monitor the position of the eyes such that when a character within a two dimensional array is eyeballed, it is reproduced upon an electric typewriter.

The initial application of the equipment will be for a cerebral palsied girl who presently communicates mainly via eye movements using a display board as described in a paper by M. Rosen et al [1] However, the design could be used without modification . by anyone having normal control of eve movements.

OPTICAL DESIGN

The device uses corneal reflection in order to monitor the eye position. A light-emitting diode (LED) driven by a 1 kHz square wave, launches about 10 microwatts of infra-red light of wavelength 820 nm into a step index optical fibre leading to the transducer assembly immediately in front of one eye. The fiber defines the size and beamspread of the corneal irradiation, and also ensures that no electrical crosstalk to the sensing circuitry is possible.

Radiation reflected from the eye is directed upon a monolithic silicon photodetector partitioned into four quadrants A,B,C, and D. By analysing the distribution of light into two signals A+B-C-D and A+C-B-D, a two dimensional analogue estimation of the eyeball orientation is achieved. Background light effects are eliminated by demodulating the 1 kHz component using synchronous detection followed by low pass filters with a bandwidth of about 2 Hz, sufficient to pass the signals generated from eye movements resulting from character selection.

The characters are viewed through an acrylic aspheric lens of focal length 27 mm. They appear in an 8x8 array formed on a 25 mm square transparency (Fig. 1). Total eye movement to be monitored is then 46 degrees in both axes. The eyes are at rest, viewing at apparently infinite distance. Backlighting is provided by the room environment. Additionally, when a character is selected, confirmation is supplied by illumination from a red LED behind it.

A coaxial system is used for the two optical functions of viewing and position monitoring (Fig. 2). The infrared light is introduced in the centre of the character array, whilst the reflected light is diverted by a glass beamsplitter angled at 45, and positioned between the viewing lens and the transparency. Thus only one eye is obscured by the transducer, the other being free to observe the room environment. The transducer assembly is referenced by mechanical supports to the forehead and the bridge of the nose. A cable harness containing the optical fibre and the electrical connections to the photodetector and the confirmatory backlights leads from the transducer to the nearby box of processing electronics.

SIGNAL PROCESSING

The analogue signals representing the horizontal and vertical positions of the eye, are digitized and presented to a single-chip microprocessor (Intel 8748). This device contains a central processing unit, 64 bytes of random access memory and up to 1 kilobyte of erasable programmable read only memory (EPROM). It is programmed to interpret the signals, activate the confirmatory backlights and put out the corresponding ASCII character code to a parallel printer interface and to a RS232 serial port.

The operating procedure is as follows: 1-. After the headset has been put on and the equipment switched on by the users helper, a user-controlled alignment procedure is initiated. 2-. A character is selected for printing by eyeballing it. 3-. When the eye position has been determined, the LED behind the selected character is turned on. 4-. If the eye dwells a little longer upon the character, its ASCII code is sent to the printer, and a brief tone from the equipment speaker signals that the next character should be selected. The initial reaction time of the system allows a printing rate of about one character every two seconds.

The design was guided by the desire to keep the equipment simple and low cost, whilst providing maximum independence for the user. Some of the features that satisfy this are: 1-. The electronics including the power supply fit into a box smaller than the common telephone set. 2-. The sensor system is aligned electronically, obviating the need for a precise mechanical alignment procedure. 3-. The system automatically adapts to slow changes in the eye-to-sensor relationship. 4-. The user can initiate re-alignment if required. 5-. The user can switch the equipment on and off. 6-. The user can control the speed between 0.1 and 5 characters per second. 7-. No connections are required to the body. 8-. Head movements are not restricted.

STATUS

A prototype has been built and tests are continuing, using the authors as test subjects. Some problems have been encountered from unwanted internal reflections and transducer nonlinearity which could reduce the number of characters permitted. The mounting of the headset may also need refinements. Sketches of the equipment and program listings are available to those interested.

FUTURE POSSIBILITIES

Changes to the list of features are expected to result from comments of the user. Improvements that are already considered include: 1-. An output that simulates an Apple keyboard. 2-. A solid state display that allows conversational messages to be displayed without the use of a printer. 3-. When using a printer, this display could be used to preview and edit a line before actually printing it. 4-. A voice synthesizer chip could be used to confirm character selection instead of the LED matrix within the transducer, thus substantially reducing the weight of the transducer and harness.

CONCLUSIONS

Design and experiment indicate that it is possible to operate sophisticated equipment using a relatively simple and low cost monitor of eye movement.

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ACKNOWLEDGEMENTS

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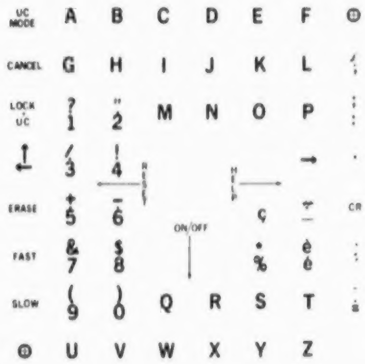

Fig 1 Character Array

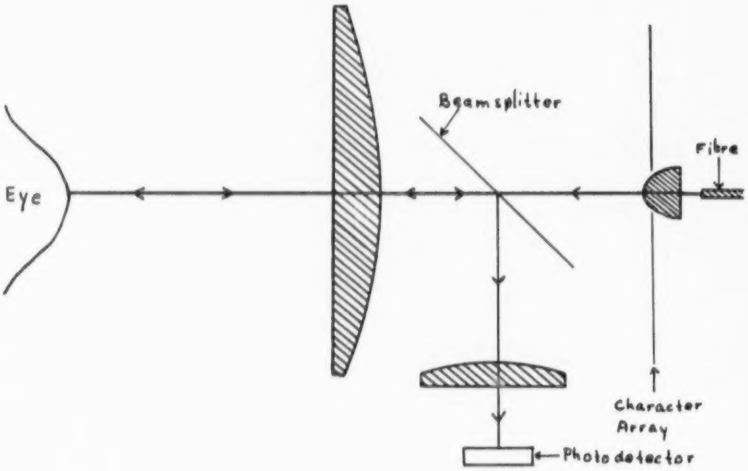

Fig 2 Sideview of Optical Design

SPEECH AS A MEDIUM FOR INTERFACING DISABLED PEOPLE TO AIDS

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ABSTRACT - Recent advances in microelectronics have led to the availability of low-cost speech recognisers. This paper discusses their potential in interfacing disabled people to assistive aids. Applications to aid mobility, independent living and communication are described and critically assessed.

RÉSUMÉ - Grâce aux progrès récents en micro-électronique on trouve des reconnaisseurs de la parole peu chers. Cet article discutte de leur potentiel en tant qu'interface entre les handicapés et les appareils dont ils se servent. Il évalue aussi les applications qui améliorent la mobilité, l'indépendence et la communication.

Introduction

As a result of recent advances in microelectronics, low-cost speech recognition devices have started to appear on the market. These achieve sufficiently good performance to be seriously considered as alternatives to conventional computer-input devices. As such, they offer a new way to interface physically disabled people to their assistive aids. This paper explores the potential of speech as such an interfacing medium.

Available recognisers are essentially acoustic word-matching devices based on general statistical pattern-recognition techniques. Little use is made of the fact that the input (speech) has special properties distinguishing it from other signals. As a consequence of these operating principles, current devices have a number of limitations. Typically, these are:

* isolated-word input
* small vocabulary
* speaker-dependent
* poor noise immunity

Connected-word capability and a measure of speaker independence are available in certain newer devices, but a penalty has to be paid in terms of cost and/or vocabulary size. For the immediate future, then, we are practically restricted to applications involving discrimination of a small set of isolated words, spoken by a user who has previously "trained" the system. Fortunately, many voice-control possibilities for the physically disabled remain.

Interfacing the Disabled to Aids

Conventionally, interfacing schemes may be classified as (1):

* direct selection
* encoding
* scanning

Direct selection is potentially fast but requires the number of input actions the user can made (n) to exceed the number of response alternatives (N). Encoding reduces the set of input actions necessary to make selections, n<N. This can be a useful way of coping with technological limitations or user disability. Scanning input is very slow but can be used by the most disabled of people. It is characterised by the need to make one distinct input action only (n=1) when a cursor is positioned over the desired selection. The distinction between scanning and encoded input has been blurred by some authors who describe two- or three-switch "scanning" schemes which are properly encoding devices. Thus, on grounds of input speed, direct selection should be used if at all possible, whereas scanning is a "last resort". Viewed within this framework, what advantages does speech input offer over "conventional" interfaces (suck-puff tubes, palate switches, etc.)? Perhaps the major advantage is high signal dimensionality. Assuming the user has normal speech, n is only limited by the size of vocabulary the recogniser can handle without an unacceptably high error rate. Thus, use of speech may enable us to replace a scanning scheme by encoded input or even direct selection. Use of speech is "natural" - exploiting a highly developed ability like speech is preferable to the use of an unnatural eye, palate or eyebrow movements, for instance. Unfortunately, however, speech subserves many functions and these can interfere with voice control. For instance, conversation may be inhibited and some people like to talk to themselves as they concentrate on a task. Finally, control is remote (and so hygenic) offering the promise of greater user mobility.

Against these advantages must be weighed certain disadvantages. The need to "train" the recogniser and poor performance in the presence of background noise were mentioned above. Because of the pattern-matching approach, performance tends to be sensitive to intra-speaker variability. In many cases, users who find it difficult to constrain their speech to achieve good performance are unable to use voice control. To the naive user, the reasons for a misrecognition error can be very obsure. Simple repetition of the misrecognised word with increased stress is more likely to lead to further errors than to cure the problem. The choice of feedback medium and the information provided can all have a profound effect on error performance. Finally, the cost of speech recognition devices is, at present, relatively high compared to pneumatic and electromechanical switches. With advances in microelectronics technology, however, this could well change in the near future.

Applications of Speech Recognition to Aid the Disabled

Speech recognition can aid the physically disabled in the areas of mobility, independent living and communication. Applications which have been reported are:

- wheelchair control (2)
- environmental control (2,3)
- manipulator control (4)
- text composition (5,6)
- computer access (7)

Wheelchair control is not, in my opinion, a very suitable application. For safety reasons, fast accurate responses are essential and this makes established controls preferable. Further, proportional control is preferable to the inherently discretised input which results from speech recognition.

The tasks involved in environmental control (with the possible exception of alarms and emergency communications) are essentially non-critical. This is, therefore a much more suitable application within which to investigate the potential of a new interface technology of unproven value and our early work (3) concentrated on this application. Problems of discrete (rather than proportional) input remain as in e.g. TV volume control, but are less severe.

The environmental control unit suffers from a fixed repertoire of actions. By contrast, a robotic arm or manipulator is a very flexible aid. Voice control of such a device has been investigated (4) but this application appears to have a number of drawbacks. The cost of such manipulators is at the moment rather high although, again, this is likely to fall with increased industrial usage. More importantly, the safety consequences of misrecognition or other operating errors are potentially serious. Also, the user may view the assistive device as a prosthesis, probably depending upon its physical proximity. Speech would appear to be a very unnatural way to control a prosthesis, and biological (muscular or electrophysiological) control is to be preferred.

Computer access is closely related to text composition. Text composition and editing is a demanding application because of the crucial need for reasonably fast input. When speech recognition is used, it is necessary to obtain access to unlimited vocabulary with a restricted-vocabulary recogniser. As we have seen, however, speech interfacing is likely to be an improvement over conventional interfacing in many cases, by increasing the number of input actions which the severely disabled user is capable of making. The ideal scheme would be direct selection of (all) words, but this is far beyond the capabilities of current systems. Letters can, however, be selected directly, mimicking QWERTY keyboard input. It is necessary to use the phonetically-distinct Pilot's Alphabet (ALPHA, BRAVO, CHARLIE ..) rather than conventional letter names (EH, BEE, CEE ...). Existing systems using this approach achieve text composition rates of some 30-35 char/min.

Encoded selection of letters has also been investigated: letters are selected from a displayed two-dimensional matrix by spoken co-ordinates. This is rather slow (about 15 char/min) as two input utterances are required per letter. However, the cognitive load of remembering the Pilots' Alphabet and translating letter names is removed. We have also experimented with encoded selection of common words (6).

A great many options are available to the system designer. For instance, encoded selection of graphemes, or selecting from word lists accessed by direct selection of initial letter. We have also combined direct selection of the 10 most-common words (which account for some 24% of printed text) with certain of the above approaches. Present work is investigating the use of mathematical models to guide the choice of optimum text-composition strategy.

Conclusion

Speech recognition technology offers a new way of interfacing disabled people to aids. Although having many potential advantages, the full benefits will not be realised without careful system design which takes into account the unique characteristics of speech.

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EVOLUTION OF A VOCABULARY FOR VOICE CONTROL OF A ROBOTIC ARM

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ABSTRACT - A voice recognition unit gives less recognition errors when reciting command words than in the context of controlling a robot, suggesting that device evaluation must consider emotional, semantic as well as phonetic parameters. Methods are discussed and tools for improving vocabularies are proposed.

RÉSUMÉ - Une unité de reconnaissance de la voix donne de meilleures résultats en lui récitant une liste de mois que dans le contexte du contrôle d'un robot, ce qui suggère que l'évaluation d'une telle unité devrait considérer des facteurs émotionnels et sémantiques ainsi que phonétiques. Des méthodes et des résultats sont présentés pour l'amérioration d'un vocabulaire de commande.

INTRODUCTION

Speech may be one of the only remaining modes of communication for people suffering from high-level spinal cord injuries or degenerative neurological diseases, indicating that voice recognition units (VRU's) are potentially powerful communication devices. In the use of VRU's, sources of recognition error can be classified (see Figure 1) into two major categories: phonation and semantics. Systematic evaluation procedures centering on interviews with users, on the comparison of the voice reference templates, and on the tallying of recognition errors has formed the basis for changes made in a command vocabulary used for control of a robot.

BACKGROUND

Aspects of Speech Recognition

For certain disabled persons, phonation can be a major problem. For example, quadriplegics may have partial paralysis of the larynx or muscles of respiration (Moore, 1971). We have found that consistency of phonation is a problem for all users. Speech variations can be linked to emotion and stress (Wicke et al., 1983), adaptation to the control of the robot and the style of user training (Awad et al., 1983).

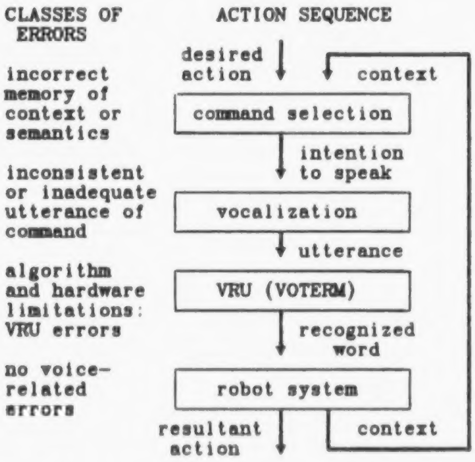

FIGURE 1. SOURCES OF VOICE-RELATED ERRORS

Voice Recognition Studies

An important measure of comparison between VRU's is the maximum recognition accuracy in controlled settings. Interstate Electronics claims a 99+% recognition rate for their VOTERM unit (VOTERM manual). These studies, however, do not show performance under actual usage.

METHODS AND MATERIALS

Robot System Architecture

The VA/Stanford system (Leifer, 1981) employs a user-dependent VRU (a VOTERM) since such technology offers much better recognition and greater vocabulary size than user-independent units. The system also contains a Unimation PUMA-250 arm, a VOTRAX speech synthesis unit, a Zilog MCZ microcomputer system, and various displays and peripherals. The software permits real-time control of the piloting process (Buckley & Leifer, 1982), in addition to command of robot system functions.

The VOTERM hardware consists of 16 band-pass filters, each producing one bit of data (amplitude comparison to a threshold) per 5-msec sample. Dynamic time-warping is performed to reduce data storage needs and to adapt to varying speech rates. Resultant templates are stored for future use. They are also available to the VDELTA template comparison program for the purpose of studying vocabulary words from the VRU's phonetic point of view.

Voice Training and Sessions of Robot Use

Each user requires a training phase in which the vocabulary words are repeated 3 to 6 times for the VRU to create its reference templates. The arm control program ARMC uses the VRU in recognition mode, and executes the voice commands.

During a user session an observer tallies all errors related to the use of the vocabulary: context-related errors, invalid words used, VRU rejections, and VRU substitutions. Figure 1 illustrates the source of these errors. The tallying is transfered to a data analysis program.

RESULTS

Evolution of the Command Vocabulary

The command vocabulary has undergone three revisions, culminating in V4. Figure 2 is an excerpt of the entire vocabulary evolution, with indications as to which factors went into the decision to change a word. The following sections will illustrate some specific cases. Factors (a) and (b) relate directly to Figure 1. Factor (c) encompasses changes unrelated to phonologic questions.

Classification of Voice Command Related Errors

The first phase of the tally data analysis (30 user sessions of 90 minutes each) is illustrated in Figure 3. In version V3, "GO LEFT" replaced "LEFT" in V2 because of VRU substitution of similar words whose initial consonant was not a plosive. "GO LEFT" produced better recognition overall, but was unnatural since other piloting words, like "UP", did not have the "GO" prefix. We thus reverted to "LEFT" in V4, and removed words of possible phonetic similarity. Results show an increase in substitutions, but a decrease in invalid word use and an improvement overall (see Figure 3).

Another example, the change of "POISE" to "ZERO", was done using VDELTA to first explore alternatives. We achieved an increase in recognition from 67% to 86%.

Cmd	V-2 →		V-3 →		V-4
3.	CLOSE	a	GRIP	b	CLOSE
5.	SPEED UP	ab	FASTER		FASTER
6.	SLOW DOWN	ab	SLOWER		SLOWER
12.	TOOL	a	PILOT		PILOT
19.	NEST	a	PARK		PARK
20.	POISE		POISE	a	ZERO
21.	REVERT		REVERT	c	PRACTICE
40.	ABOVE	ab	UP		UP
41.	BELOW	b	DOWN		DOWN
42.	LEFT	a	GO LEFT	b	LEFT
43.	RIGHT	a	GO RIGHT	b	RIGHT
46.	ARM	ab	BODY		BODY
52.	PLUS	a	CLOCK	b	PLUS
53.	MINUS	a	COUNTER	b	MINUS

Legend: a = change for phonetic reasons
b = change to make word more natural
c = change for new command function

FIGURE 2. EVOLUTION OF THE VOCABULARY: EXAMPLES

Vocabulary V3:

Command	Rec	Rej	Out	Sub	Inv	Tot	Rec %
GOLEFT	43	4	0	1	3	8	84.3%
POISE	18	5	0	4	0	9	66.7%
Totals	1345	103	15	66	12	196	87.3%
% Error		(52)	(8)	(34)	(6)		

Vocabulary V4:

Command	Rec	Rej	Out	Sub	Inv	Tot	Rec %
LEFT	224	9	1	18	1	29	88.5%
ZERO	9	11	1	1	0	13	85.9%
Totals	5248	461	104	227	14	806	86.7%
% Error		(57)	(13)	(28)	(2)		

Legend: Rec = # correct recognitions
Rej = # non-recognized utterances
Out = # out-of-context use of word
Sub = # substitutions
Inv = # invalid words used
Tot = Rej + Out + Sub + Inv
Rec%= Rec / (Tot + Rec) %

FIGURE 3. TALLY DATA TABLE EXCERPT

In both V3 and V4, the overall recognition rate was about 87%. However, the proportion of invalid word usage and VRU substitution errors decreased from 6% to 2% and from 34% to 28%, respectively. This indicates that users found the commands more natural and that word differentiability had been enhanced. VRU rejections went up from 52% to 57% of total errors, an anticipated corollary.

Template Differentiability

A comparison of templates gives a measure of phonetic similarity between words. One can minimize VRU substitution errors by only using words whose templates are significantly distinct. Figure 4 gives a calibration trial of the VDELTA program. Six words were used: two sets of three like-sounding words. The difference scores show close matches within sets, and good differentiation across the sets. This procedure was used to design word entries for V4.

	MOVE	TOOL	WORLD	NEST	YES	LEFT
MOVE	0	39	36	66	63	61
TOOL	45	0	46	69	63	64
WORLD	35	39	0	60	57	57
NEST	66	65	61	0	29	47
YES	74	70	69	45	0	45
LEFT	65	64	62	52	37	0

Legend: Numbers are differentiability (%) of row word from column word templates.

FIGURE 4. CALIBRATION RUN OF VDELTA PROGRAM

CONCLUSION

Our goal is the development and linking of procedures to define a set of VRU vocabulary design tools. Preliminary results from the methods we are using are statistically significant. Spectrographic analysis will be added to the methods discussed. By a combination of user training, software development, and systematic vocabulary design, we hope to improve the overall recognition rate for a voice-controlled robot.

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THE VOICE RECOGNITION DEVICE FOR COMPUTER CONTROL BY MOTORICALLY- AND SPEECH-IMPAIRED INDIVIDUALS

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ABSTRACT - This presentation will describe the implementation of a voice recognition device interfaced with an Apple II for computer control by one 9 year old quadriplegic boy. A preliminary evaluation of the VIM-II, a voice template matching device, for speech- and motor-disabled individuals will be discussed.

RÉSUMÉ - La présente communication décrit comment est réalisé l'interfaçage d'une unité de reconnaissance de la parole et d'un microordinateur Apple II permettant à un quadraplégique de 9 ans de commander ce dernier. Est présentée une évaluation préliminaire du VIM-II, dispositif de comparaison de modèles sonores, destiné aux personnes souffrant de troubles de la parole et de motricité.

INTRODUCTION

The voice recognition device has been identified as an interface which gives certain neurologically impaired individuals the ability to independently control the personal computer. The device is potentially useful for patients with spinal cord injury and certain degenerative diseases, such as muscular dystrophy. These individuals demonstrate adequate speech and language skills with intact cognitive abilities.

Spinal cord injury at the C1-C2 level results in paralysis of all extremities. Cognitive and language skills often remain intact. Articulatory ability is usually maintained, but voice intensity and duration are reduced due to respirator dependence. Because of severe mobility limitations, the child with spinal cord injury is rarely able to increase cognitive/language skills through active, independent experiences. The relatively inexpensive availability of the personal computer and voice recognition systems, as well as off-the-shelf educational software now offer the motor impaired child a unique means to actively learn and affect experiences through voice-activated computer control.

THE VOICE RECOGNITION DEVICE

Voice Input Module-II, a device manufactured by Voice Machine Communications, Inc. of Santa Ana, California, has been identified as a voice recognition system that contains its own microprocessor and keyboard interface and translates vocal productions into keyboard entries for conventional Apple computer use. The system is trained to recognize user-defined vocabularies that can be stored and recalled without hardware or software modifications. Vocabulary items may include computer commands (i.e., 'escape,' 'catalog'), as well as items that are traditionally typed out letter-by-letter on the keyboard. Since the device often confuses phonetically similar entries (i.e., the letter names for b,d,t,p), letters are usually represented with a standard code (A-Alpha; B-Bravo; C-Charlie). The user simply speaks into a microphone to create a vocabulary file that can hold up to 80 entries. The VIM-II boasts of a 95% accuracy for voice entry recognition.

The device was tested for recognition rate accuracy. Table I lists obtained recognition rates.

TABLE I
VIM RECOGNITION ACCURACY RATES

speaker	# utterances	% recognition
28 y.o. female	100	96%
29 y.o. female	50	98%
32 y.o. female	50	90%
40 y.o. male	75	92%

The VIM-II was judged as an excellent candidate for technological enhancement of the speech- and/or motor-impaired individual's daily functioning. If the device could be shown to be reliable for voice activation of the personal computer by the disabled individual, then it could be chosen as an interface to control environmental manipulators and computer-based stations for educational and vocational goals (1, 2, 3). The VIM-II was introduced to one quadriplegic child (PB), and is presently being tested with dysarthric individuals (4).

PB - A CASE STUDY

PB, a 10 year old male, incurred a C1-C2 injury 3 years ago which left him paralyzed but cognitively intact. Academically, he now functions at the 4th grade level. He uses a portable respirator and deflated cuff which permit some vocal productions. PB can now maintain voice for a 6 to 8 word sentence, with resulting reduction in intensity. He was recently seen at this Rehabilitation Institute to determine if an independent means of computer control could be found to increase his academic skills, his motivation to learn and his environmental control.

It was decided to introduce PB to a voice recognition device that could be interfaced with his Apple computer. With this new device, the patient could be taught to manipulate educational software programs, thus independently affecting his learning and recreational environment. It was expected that a voice recognition system would not function as well for a respirator-bound child's voice with reduced intensity and limited duration. PB trained the VIM-Apple system to recognize 23 phonetically distinct computer commands needed to run an elementary mathematics software package. He was able to run the program inconsistently. Due to fluctuations in vocal productions, interfering noise from the uncuffed tracheostomy, and unreliable recognition of a high pitched voice, recognition rates only ranged from 40% to 60% for a total of 273 utterances.

Despite the limited recognition rate, PB displayed increased motivation to learn, and expressed a desire to continue using the voice activation system. The new found independence and reported computer use, thus, support the introduction of a voice activated system for the quadriplegic child.

A PROPOSED STUDY

Since the voice recognition system merely matches created templates to spontaneous entries, the device is potentially useful for the speech-impaired individual who can produce a number of phonetically distinct, albeit unintelligible, vocal productions. In principle, the device should match virtually any utterances. A moderately intelligible dysarthric individual should be able to access voice templates as successfully as the normal speaker if the speech patterns are produced in a consistent manner during vocabulary building and usage. Since the device is not intelligent, it doesn't matter if the word "print" is produced accurately or with distortions (/bit/). As long as the productions are consistent, the device should work. A study is presently being conducted to determine if the voice recognition device can, indeed, function successfully with mild to moderately impaired speech input. Dysarthric individuals are being tested with the VIM-Apple II system to ascertain recognition rates and device utility for this disabled population. The hypotheses being tested are:

(1) The voice recognition device will successfully match stored templates to dysarthric productions of words, commands and alphanumeric codes spoken by the same individual with 75% accuracy.

(2) There will not be a significant difference between the relative accuracy rates for template matching between normal and dysarthric speakers on the voice recognition device.

Preliminary results of this study will be reported.

ACKNOWLEDGEMENT

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OPTIMIZING THE VOCABULARY ORGANIZATION OF AN "EYETRACKER" COMMUNICATION DEVICE FOR NON-VOCAL ELEMENTARY SCHOOL CHILDREN

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ABSTRACT - Research is being conducted to optimize the organization of words in an eye-gaze based communiction device designed for primary school children. Words are presented as displays of up to 16 words, which are "paged" by the users.

RÉSUMÉ - Des recherches sont en cours pour optimiser l'organisation des mots dans un appareil de communication basé sur le regard destiné à des enfants d'âge scolaire. L'appareil peut afficher jusqu'à 16 mots qui sont "feuilletés" par l'utilisateur.

An eye-tracking device can provide the most rapid and least fatiguing means of control of communication devices for many physically handicapped, non-vocal people. The EyeTracker Communication System, developed at the Rehabilitation Institute of Pittsburgh, differs from other prototype eye-tracking systems in that it is based on word rather than letter selection and it has the most extensive history of field use. Two units have been used for over a year each - one in a child's home, the other in a public primary school. Another unit has been used for over two years in a laboratory environment. This paper describes our attempt to optimize an eye-based communication system for use by severely physically handicapped older primary school children.

Typically, human eye position is monitored by using electrodes on the face, photosensors on frames around the eyes, or by imaging the eyes with a remote camera. Because of the enhanced margin of safety provided by not having any physical contact between the user and the eye-position sensor, the EyeTracker System is based on the infra-red image of the user's eye as seen by a remote camera.

The present EyeTracker communication aid looks like a computer terminal that has eight one line liquid crystal displays arranged around the periphery of a 3 x 3 matrix. In the center of the display array is a hole through which an internal camera views the user's eyes. Also inside the case, near the hole, is a small, red-filtered, incandescent light bulb whose reflected image is used to help determine the direction of the user's gaze. The user controls high quality speech output by using her eyes to look at one of the eight displays of words and short phrases.

In one mode of use, the non-vocal child selects answers to questions by gazing at a fixed set of eight words and phrases entered by a parent, teacher, or therapist from an attached keyboard. In another mode of use, the child can use her eyes to page through a long list of words stored in the machine's bubble memory, before making a selection. Clearly, replacing the eight alpha-numeric displays with bit-mapped graphic displays would extend use of the EyeTracker to children who cannot read but who can recognize pictographic symbols.

Current research is directed toward enhancing the rate of communication of non-vocal primary school children who can read but who do not yet have the ability to rapidly spell the vocabulary needed for basic social and educational communication. We have recorded and transcribed all the questions asked of and replies given by vocal children with severe cerebral palsy. After obtaining the permission of the parents, teachers, and children, voice activated cassette recorders were placed on the children's wheel chairs during full school days. Since recording was voice activated, tapes rarely needed to be replaced during the day.

Although the children's comprehension is much greater, each child's spoken vocabulary consists of only about 1000 words. We are simulating displays of up to 16 items per "page" and organizing these "video pages" so that children can rapidly sequence through the pages to select the words they want. We are comparing the relative efficiency (as measured by total time and cumulative acts of selection) of various organizations of the children's core vocabulary. Tree-structured and other hierarchical context dependent linkages between word groupings are being compared to alphabetic dictionary and thesaurus organizations of the same vocabulary.

Following the results of these keyboard based simulations of vocabulary organization, assayed by using samples of actual dialog, we will incorporate the preferred data structure into a new eye-tracking communication aid built on a commercially available eye-controlled keyboard (From Sentient Systems Technology, Inc., 5001 Baum Boulevard, Pittsburgh, PA 15213) and a commercial microcomputer.

THE OCUCOM
AN EYE POSITION COMMUNICATIONS/CONTROL DEVICE

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ABSTRACT - A practical communications/control device for use by severely disabled individuals is described. The different modes of operations are discussed and results of the users are presented.

RÉSUMÉ - Description d'un appareil pratique de communications/contrôle à l'usage de personnes sévèrement handicapées. Discussion des différentes méthodes de fonctionnement et présentation des résultats après l'utilisation de cet appareil par les handicapés.

Introduction

The development and evaluation of the ocular communicating control device has been in process at the University of Denver for the past eight years. A suitable device for detecting eye positioning has been developed. Communications quickly became the most important application.

The objective of the present device has been to develop a unit that can be controlled by use of eyes only, can be easily set up by untrained personnel, and will be comfortable and obstruct normal vision as little as possible. The unit that has resulted accomplishes these objectives.

The Communicator

The communication/control device uses a Rockwell 6502 microprocessor to acquire and decode eye position data and generate the corresponding character or control function, and provides all necessary digitally coded output to peripheral devices. The unit is shown in Figure 1. It is contained in a 12" x 9" x 5" aluminum case with carrying handle. The top of the case opens to allow access to the controls and the alphanumeric display. The program for operation is contained in 4K bytes of RAM and there is an additional 1K bytes of non-volatile RAM for stored messages. The unit is self contained and can be used without external devices. Ports are provided to allow external connection to other devices.

Interfacing to accessory devices is accomplished by means of analog switches. Thus, virtually anything that is operated with push buttons can be easily interfaced to the device. For environmental control applications the unit is interfaced by these analog switches to a Sears and Roebuck Home Control System (TM). This and similar carrier type systems are available at low cost. The control unit operates modules which are merely plugged into the power line. No external control cable is required and up to sixteen (16) individual items can be controlled.

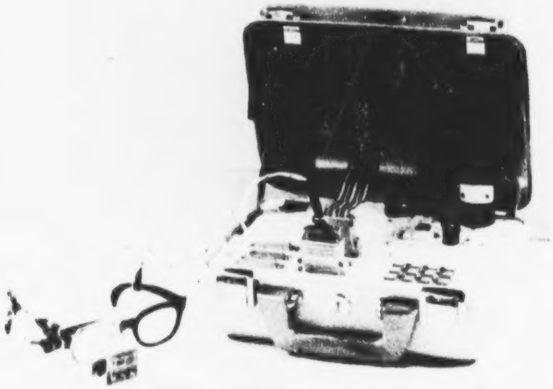

Figure 1
THE OCUCOM DEVICE

The ocular transducer which uses corneal reflection to determine eye position was described by Rinard and Rugg (1976). The transducer detects the corneal reflection of an infrared LED by means of a 32 x 32 matrix image sensor (1024 dynamic RAM). The signal thus derived is the digitally encoded position of the eye. See Rinard et al., (1980). All components are mounted on an ordinary pair of eyeglasses and an infrared mirror is utilized to allow the eye position to be detected without interfering with normal vision.

A safety analysis of the device was conducted. Safety levels were based on the American National Standard for the Safe Use of Lasers and the American Conference of Governmental Industrial Hygienists TLV's for 1979. It was concluded that the device has no potential for harm to the eye when used for an unlimited period of time as long as the near focal point of the user's eye is not less than 4 cm (25 diopters).

The communicator/controller utilizes an encoding technique to allow direct selection of characters and control functions. Considerable work has been done to determine the best mode for selection. Two modes have proven to be satisfactory. The difference in these two modes is in the number of fixation points the eye must make to encode a character. These are three (3) and nine (9) positions respectively. Each mode has advantages for specific users.

The mode three scheme is based on the Morse code. The glasses with target for mode three are shown in Figure 2. The arrangement shown in the figure is to mount the target with the three fixation points in the lower portion of the user's field of view. This bifocal type arrangement allows the use of prescription lenses in the upper portion of the field of view and is very good for applications requiring unobstructed vision. Some users with eye movement impairment also find this mode easier to use.

Mode nine is based on the ETRAN scheme as described in Rinard and Rugg (1978). The glasses with the target for mode nine are shown in Figure 1. The advantages of this scheme is that the encoding sequence necessary to select a character is obvious from its location on the ETRAN chart. As a result user training time is usually quite short. The operating speed is also potentially higher with the ETRAN scheme. The disadvantage of this scheme is that vision in one eye is completely obstructed. Also some potential users do not have sufficiently good eye control to effectively utilize the mode nine scheme.

Clinical Testing

The ocular communicator device has been tested with a number of individuals. Those tested included people with high level spinal cord or brain stem trauma, brain stem stroke, cerebral palsy and amyotrophic lateral sclerosis (ALS). S.H., with a high level brain stem trauma, was one of the most successful users. He was able to utilize the mode nine system in spite of severe nystagmus. S.H. used the communicator in his home for interactive communication with other members of his family for approximately one year. The speed of operation he achieved was approximately four to six words per minute.

The best results to date have been with ALS patients. There is usually no impairment in eye control with ALS until the last stages of the disorder. This probably is one of the reasons for good success with these patients. Two ALS patients each utilized the communicator in their homes for approximately one year. The communicator provided both a means for interactive communication with their family and both utilized the mode nine operation.

In all cases with individuals using the communicator in their homes, adjustments and set up of the device were done by an assisting family member. Training of the assistants required about four hours over a period of two days time. All became adept at setting up the device very quickly, however, they required a few weeks before they felt comfortable at making adjustments of the glasses themselves. It is felt that the adaptive nature of the set up procedure reduces training time required for these assistants.

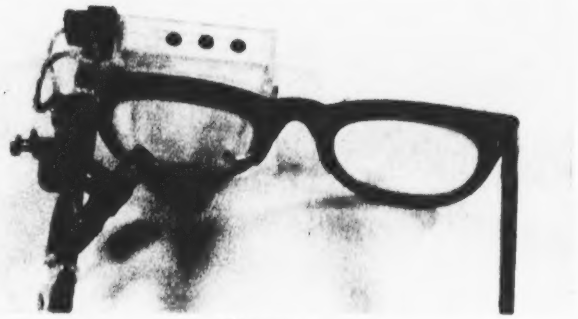

Figure 2
GLASSES FOR USE WITH MODE THREE

Concluding Remarks

The ocular communication/control device described is intended for severly disabled individuals with only eye position control. It has been shown to be effective for both communication and control applications in the user's home. The eye position detector which is mounted on an ordinary pair of glasses requires initial adjustment by a trained individual. However, later only minor adjustment is required in most cases which can be accomplished by other members of the user's family. Adjustment is critical, but an adaptive set up procedure greatly simplifies the task. It is felt that the unit provides a means of communication and control that would not otherwise be possible for very severely disabled individuals. The unit is flexible and allows the use of a number of perpherial devices. Work is presently underway to interface the unit with a wordprocessor. Mode two will be used to allow the user to see the video monitor. The control unit will replace the standard computer keyboard. It is felt that this will provide a level of sophistication that the intended user will be able to utilize.

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SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 21

POSTURAL AND SEATING AIDS/
AIDES POUR LA POSTURE ET LA POSITION ASSISE

A COMPARISON OF THE PRESSURE RELIEF CHARACTERISTICS OF TWO AIR FLOTATION BEDS

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In this study the pressure relief characteristics of the two most popular air flotation beds have been evaluated. No significant statistical differences were found between the pressures recorded under people lying on either the Clinitron or the Mediscus beds.

Dans cette investigation les caractéristiques du soulagement de la pression des deux lits "air flotation" les plus populaires ont été évaluées. Les statistiques n'ont montré aucune différence entre les pressions enregistrées sous les gens couchés sur les lits Clinitron on les lit Mediscus.

INTRODUCTION

The need for tissue pressure management during confinement in acute care hospitals and in nursing homes is becoming a topic of increasing concern in order to reduce the occurrence of secondary complications. In response to this potential market, a number of therapeutic bed surfaces and flotation beds have been developed and are commercially available. The marketing claims for these devices are impressive but there have been limited independent evaluations of the devices. The Rehabilitation Engineering Department (RED) at the Institute for Rehabilitation and Research (TIRR) has evaluated a number of the most popular therapeutic bed surfaces and the results of the study have been previously reported.(1) In response to the increasing usage of air flotation beds, an effort to reduce the need for 2 hour turning schedules and the associated manpower requirements, the RED has evaluated the pressure relief characteristics of two air flotation bed systems, the Clinitron bed and the Mediscus bed.

The Mediscus bed is comprised of air inflated pillows that permit a controlled amount of air to escape from them; the pillows are connected to 5 manifolds so that the stiffness of the support surface can be adjusted independently under the head, thorax, abdominal area, legs, and feet. The Clinitron bed uses an air fluidized bead support system that provides a uniform stiffness over the entire support surface.

OBJECTIVE

The objective of this study is to compare the effectiveness of the Mediscus and Clinitron beds in providing pressure relief and redistributing loads away from areas of bony prominence and to determine if the body build of the person lying on the bed affects the relative effectiveness.

METHODOLOGY

Subjects were chosen from patients and employees at TIRR and based on sex, height, weight and age were classified as thin, average or obese in accordance with tabulated norms.(2)

	Thin	Average	Heavy	Total
Male	2	3	3	8
Female	3	2	1	6
Total	5	5	4	14

The pressure measurements were made using a Texas Interface Pressure Evaluator (TIPE). Subjects were tested while lying in the supine and sidelying positions. The bony areas that were monitored during the data collection sessions were the scapulae, sacral-coccygeal region and trochanters. Prior to testing, the subjects were instructed to remove all objects from their pockets, remove their belts, and remove their shoes. The transducer pad was then placed between the bed surface and the areas of the subject's body that were to be monitored. The bony prominences were palpated and the corresponding lights on the readout display were noted on the data collection form. The magnitude of the maximum pressure under each bony prominence was then recorded. To assure reproducibility and improve the precision of the data, the maximum pressure readings were taken three times and the average of the three readings was recorded for each bony prominence. The sidelying position was standardized for all subjects by using a goniometer to position the hips in 45° of flexion. The trunk was positioned perpendicularly to the bed surface and parallel to the long axis of the mattress. Each subject was instructed to remain still while the readings were taken. The scapular and sacral pressure measurements were taken while the subjects were lying in a supine position.

In order to minimize the chances of introducing an artifact due to minor variations in body weight that can occur from one day to another, each subject was evaluated on both beds on the same day within a 1 1/2 hour time block either before or after lunch.

RESULTS

The results of this investigation are based on an analysis of the maximum pressure measured under the bony prominences on each of these beds. The data are summarized in Table 2.

MEDISCUS vs CLINITRON
PRESSURE READINGS
(all readings in mmHg)

MEDISCUS

Body Build	Location	Range	Mean
Thin	Scapular	18-30	22
	Sacr.-Coccygeal	18-28	23
	Heel	17-32	22
Normal	Scapular	17-24	19
	Sacr.-Coccygeal	18-23	21
	Heel	18-30	22
Heavy	Scapular	20-26	22
	Sacr.-Coccygeal	22-28	24
	Heel	18-29	22

CLINITRON

Body Build	Location	Range	Mean
Thin	Scapular	16-24	19
	Sacr.-Coccygeal	16-28	21
	Heel	18-28	24
Normal	Scapular	16-20	18
	Sacr.-Coccygeal	18-22	19
	Heel	17-29	25
Heavy	Scapular	17-19	18
	Sacr.-Coccygeal	16-23	19
	Heel	15-30	23

An analysis of the statistical significance of the differences in the means was conducted using the Student T Test; the results of this analysis are given in Table 3.

"T" Test Summary	Mediscus vs Clinitron
Pressure Site	Level of Significance
Trochanter	No sig.
Scapula	No sig.
Sacral-Coccygeal	No sig.

There are no statistical differences in the data collected in this study. However, the same pressure readings could be obtained on the Mediscus bed for a family of pressure settings. As long as the relative stiffness of the five bed sections was kept constant, the pressure readings remained unchanged so the bed could be very soft or quite firm.

CONCLUSIONS

Based on the results of this investigation the following conclusions have been developed:

1) There is no difference in the pressure reduction and redistribution characteristics of the Mediscus and Clinitron beds when the devices are properly adjusted.
2) The effectiveness of the two beds is independent of the user's body build.
3) The Mediscus bed requires a trained person to adjust the air sacks to achieve minimal pressures.
4) The Mediscus bed is easier to transfer patients from.
5) The Mediscus bed provides for varying posture with no effects on the pressure loading.
6) After a person is suspended on the Clinitron bed, the power can be turned off and the pressures will remain unchanged as long as the person does not move at all.

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DEVELOPMENT OF A COMPUTER-AIDED WHEELCHAIR CUSHION FITTING CLINIC FOR THE PREVENTION OF PRESSURE SORES

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ABSTRACT - A computer program has been developed to assist in the decision making process of fitting wheelchair cushions to prevent pressure sores. Evaluations show that the system improves the effectiveness of the clinic and also provides for the transfer of cushion fitting expertise.

RÉSUMÉ - Un programme machine a été mis au point pour faciliter le processus de prise des décisions lors de l'ajustement des coussins d'un fauteuil roulant pour empêcher les plaies dues à la pression. Les évaluations révèlent que le système améliore l'efficacité de la clinique et assure le transfert des connaissances relatives à l'ajustement des coussins.

Introduction

Pressure sores continue to be a major concern for the physically handicapped. Often requiring lengthy periods of hospitalization and treatment, these ulcerations can have lasting social and economic effects on the individual and his family. The wheelchair user in particular must develop for himself a regime of pressure sore prevention including skin checks and frequent push-ups. An important part of this program is the use of a wheelchair cushion to help distribute high pressures away from susceptible tissues over bony prominences. At Helen Hayes Hospital, a clinic was established in 1980 for the fitting and prescription of seating materials to wheelchair users on an individual basis.

Background

Attention towards the effective use of wheelchair cushions for the prevention of pressure sores began in 1972 with the development of the Pressure Clinic by John Rogers at Rancho Los Amigos Hospital. The goals of the clinic were the reduction of sitting pressures through the individual fitting of wheelchair cushion materials. For most of its patients, the Rancho Seating Clinic successfully used a polyurethane foam cushion which was cut out for subischial pressure relief (1).

The approach to seating used by the Helen Hayes cushion fitting service involves matching clinical needs of the patient with performance characteristics of cushion materials to arrive at an individually designed pressure relief system. The clinic makes use of both commercially available and individually modified cushions in the selection process. Modular cushion construction involving layered combinations of various seating materials is often employed at Helen Hayes (2).

While cushion fitting clinics routinely solve many difficult seating problems, drawbacks to their operation have become apparent. The key problem facing the seating team is the critical selection of a cushion from the large number currently available to the wheelchair user. This includes the wide variety of commercial products as well as those cushions fabricated by cutting out or layering standard foams. Even an experienced evaluation team cannot guarantee an efficiently accomplished match between patient and seating material.

It is the present lack of a logical organization to the fitting process and the poor transfer of expertise among existing programs that has limited the effectiveness of the clinic's performance.

Goals and Objectives

The goal of this project was to organize the cushion fitting procedure in such a way as to achieve a critical path approach to wheelchair cushion selection. This involved the following steps: first, identifying those clinical conditions necessary to describe the patient's risk of developing pressure sores. Second, matching these to the cushion specifications which would minimize this risk and finally, establishing a well structured and efficiently documented fitting procedure.

It was proposed that the most effective way of achieving this logical and repeatable approach to cushion selection was through the use of a computer in the seating evaluation clinic. The objective then was to develop a software package which would help to organize cushion selection and guide the evaluator through a minimum number of steps to cushion prescription. It was also desired that the computer program be highly interactive, user-friendly and provide a comfortable working atmosphere between the evaluation team and the patient.

Methodology

An IBM Personal Computer containing 256K of RAM memory, dual 320K disk drives, a color graphics adapter and a color monitor was used for software development and clinical evaluation. The BASIC computer language was chosen for the seating program due to its ease in establishing a highly communicative and user-friendly format which would be essential for this type of clinical computer application.

The evaluation is begun by inputting the patient's administrative, clinical, wheelchair and skin condition information. Next, the evaluator is directed to measure interface pressures on the patient's current cushion followed by reference 3 inch and 4 inch medium density polyurethane foams. The data acquired from these procedures as well as the patient's file is fed into a program manager and specifically the cushion fitting algorithm.

The cushion fitting algorithm then processes the entire patient profile and determines pressure goals as well as stability, temperature and comfort criteria for cushion selection. If the patient's current cushion or either of the reference cushions has met these goals, then the evaluation can end with a final cushion recommendation. However, in most cases, these cushions will not be acceptable and the cushion fitting algorithm must then match the clinical criteria of the patient with the performance characteristics of those cushions available from the cushion pool. One of four cushion pathways is first selected followed by a specific cushion from within that group. After the selection of a cushion, the program manager guides the evaluator through the procedures of cushion evaluation. These include the provision for a seat insert, the measurement of interface pressures and the patient's subjective evaluation of the cushion. A cushion summary chart presents an updated record of all the cushions evaluated and provides the evaluator with the option to continue along the present route, return to the cushion selection menu or end the evaluation by prescribing a cushion.

When the evaluation is continued, control returns to the cushion fitting algorithm. Once again, a matching process occurs between those criteria previously established for cushion selection and the results of the last cushion evaluated. If this match is successful and all the goals have been achieved, then a final cushion recommendation occurs. However, if there is still an unmet goal, then the algorithm returns to the cushion pool to select the next cushion for evaluation. This next cushion choice follows a computer-developed pathway for that particular patient but the option is always available for the evaluator to override the computer and select a cushion of his own.

The process of cushion selection and evaluation is continued until an acceptable seating solution is reached. The cushion is then prescribed and the patient's file permanently recorded.

Results and Discussion

Five patients were evaluated in the Helen Hayes Hospital seating clinic using the computer-aided format of cushion selection (Figure 1).

The initial results were highly favorable, demonstrating the effectiveness of the program in organization and management of the cushion fitting process. The computer demonstrated its ability to organize cushion selection into a format which no longer required an experienced seating evaluator. While expertise is still beneficial to any cushion fitting clinic, use of the program will allow smaller rehabilitation facilities to initiate such a service.

The structure afforded by the use of the computer in the clinic was in itself a time saving asset. A critical path approach to cushion selection meant fewer cushions evaluated, less transfers required by the patient and a shorter period of time spent in the clinic by both the patient and evaluator.

Use of the computer also offered an improved method of record keeping for the seating clinic. Data entry was done prior to the patient's arrival and at the end of the evalution the information was stored on a floppy disk along with a complete record of the cushion fitting procedure.

The system received a highly favorable clinical response. Use of simple instructions, logical sequences of procedures and colorful graphic presentations helped maintain a feeling of compatability rather than alienation with the computer.

Finally, the patient also benefitted from the computer-aided clinic. In an indirect manner, the computer educated the patient on wheelchair cushion selection and reinforced the importance of pressure sore prevention.

While the system as a whole performed well in these early clinical trials, the software will require further refinements to achieve an optimum level of performance. Future modifications should extend existing pathways and possibly include more seating materials to better accommodate the more difficult patient.

Figure 1

Conclusion

A current review indicates that many of the goals established during the project's conception were achieved and that there is a bright future for use of the computer in the cushion fitting clinic. While the software must be further developed to represent our present level of knowledge in cushion prescription, the system as a whole is a positive step towards pressure sore prevention in the wheelchair user. An extended period of clinical evaluations together with system modifications will help implement a routinely operating computer-aided cushion fitting clinic at Helen Hayes Hospital.

Acknowledgements: Helen Hayes Hospital is operated by the New York State Department of Health. This work was supported in part by the Walter Scott and Lyons Foundations.

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DESIGNING POLYESTER FLEECE DECUBITUS PADS

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ABSTRACT - This study has evaluated the effectiveness of various constructions of artificial sheepskins which are used to reduce harmful pressures under patients. Compression testing in the laboratory has shown that the fleece pile height and density, and the exposure to commercial laundering influence the performance of these bed sore prophylactics.

RÉSUMÉ - Au cours de cette étude, nous avons comparé différents modèles de peau de mouton synthétique utilisés pour prévenir les plaies de lit. Lors d'essais en laboratoire, le contrôle de la compressibilité a démontré que leur efficacité depend de la hauteur et de la densité de poils et du nombre de blanchissages.

Polyester fleece decubitus pads are one of the most widely used devices for the prevention and care of pressure sores because of their low cost and ease of maintenance. Prolonged exposure to pressures in excess of capillary pressure is the major etiological factor in the development of decubiti(1), yet the mechanism by which artificial sheepskins reduce pressure at the patient/support interface, and how the structure of the pad influences this mechanism are not clearly understood. The objective of this study was to identify those characteristics of fleece pads that control their ability to redistribute normal loads with a view to recommending how to improve future designs. Aware that previous attempts to evaluate these prophylactics in the clinical setting have relied on subjective assessment and have led to conflicting results(2,3,4), our approach has been to expose samples to compression testing in the laboratory(5) prior to undertaking a clinical study.

MATERIALS AND METHODS

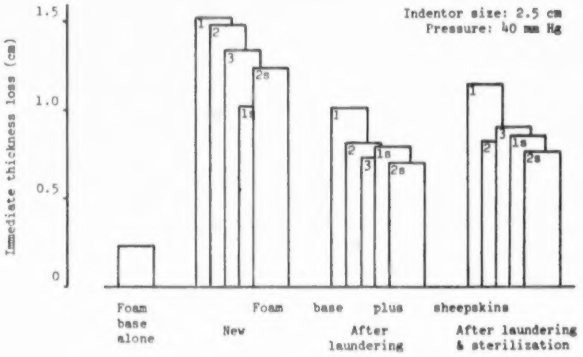
Five styles of decubitus pads were included in the study, three commercial products and two shorn variants. They provided wide ranges of physical characteristics such as mass (747-1084 g/m^2), pile height (1.45-2.15 cm) and pile density (0.022 -0.031 g/cm^3). All styles had the same silver pile weft knit construction and containes the same Type 436 Kodel polyester (polyethylene terephthalate) 6.1 dtex tubular fibers. As well as testing new pads, we conducted tests after cleaning with 5 commercial laundering cycles and after 5 laundering and steam sterilization procedures.

An Instron tensile tester was fitted with 2.5, 7.5 and 12.5 cm diameter circular indentors each of which was used to generate the testing pressures of 40 and 60 mm Hg. The specimens were supported on a block of high density foam covered with a layer of broadcloth, which provided similar support to that of a conventional hospital mattress and drawsheet, as well as serving as a control surface. The performance of each pad was assessed in terms of the immediate and delayed thickness losses of the pad/foam base combination during a 20 minute compression test.

RESULTS

When compared to the performace of the foam base alone, the addition of each new pad increased significantly the immediate thickness loss. The levels of improvement for the different pads ranged from 1.3 to 6.5 times depending on the style, the applied pressure and the indentor size used. All levels were reduced in both relative and absolute terms after laundering, whereas sterilization was found to be marginally efficacious.

Immediate Thickness Loss With and Without Sheepskins



The effect of pile height and density were analysed statistically by an analysis of variance. It showed that the pile height is the main structural characteristic that influences the performance of the pads.

Analysis of Variance of Immediate Thickness Loss as a Function of Pile Height and Pile Density

Source	Degrees of Freedom	Sum of Squares	Mean of Squares	F-ratio
Pile height	1	3.720	3.720	620.0*
Pile density	1	0.007	0.007	1.2
Pile height x pile density	1	0.060	0.060	10.0*
Error	60	0.347	0.006	

*$p<0.01$ (Pressure: 40 mm Hg, Indentor size: 2.5 cm)

The pile density was also found to be important at certain values of pile height. For example, sample no. 2 with a high pile but the lowest pile density, was actually found to concentrate the load under the indentor rather than redistribute it. In comparison with the significant immediate losses in thickness experienced at the time of loading, only minor delayed changes were observed during the subsequent 20 minute periods.

DISCUSSION

While recognising the need to confirm these results with a parallel clinical study, our preliminary findings demonstrate that fleece pads are usually more effective in distributing normal loads if they have a high pile. However, the effect of commercial laundering is to shrink the knitted fabric (7.7-15.9%) and cause the pile fibers to bend and mat. This reduces the original pile height and increases the original pile density,and explains the inferior and similar performances of all 5 styles after laundering. Sterilization has only a marginally beneficial effect, due to some relaxation of the pile fibers.

By photographing warp cross-sections through the sheepskins before and after laundering and sterilization we have been able to explain the experimental results. The smooth pile surface and uniform pile density of the new pads gives way to an irregular contour with discrete tufts and bundles of fibers after laundering. This both reduces the area available to support normal loads, and restricts the ability of the pile fibers to bend. With the least dense sample no.2, we were able to observe pile fibers bending over on themselves. Consequently the pile did not disperse the applied load to adjacent fibers outside the area of the indentor. This suggests that constructions with a high pile and low density should be avoided.

CONCLUSIONS

Knitting machines currently used to manufacture artificial sheepskins can accommodate a maximum silver length of about 2.5 cm. We believe that future designs of equipment able to knit higher and denser piles will provide improved clinical performance. At the same time alternative cleaning methods or modified laundering procedures are needed to reduce the extent of fiber matting. Health care facilities may find it advantageous to rejuvenate the pile of laundered pads by brushing or combing, as long as such procedures do not remove pile fibers and thereby significantly reduce the pile density.

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The opinions expressed herein are solely those of the authors, and do not necessarily reflect the views of the organization to which the authors are affiliated or the agencies who supported the work.

POWERED POSITIONING CHAIR, A PRELIMINARY REPORT

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ABSTRACT - The design approach and preliminary testing of a mechanized positioning device is reported as part of a larger study on the effects of postural positioning on individuals with mild to moderate Cerebral Palsy.

RÉSUMÉ - Le présent rapport fait état de la conception et des essais préliminaires d'un dispositif mécanisé de positionnement. Ces travaux font partie d'une étude plus vaste sur les effets de la posture sur des personnes souffrant de paralysie cérébrale peu ou modérément grave.

INTRODUCTION

The University of Tennessee Rehabilitation Engineering Program (UTREP) and the University of Virginia Rehabilitation Engineering Program are investigating the effect of postural positioning on individuals with mild to moderate Cerebral Palsy. EMG readings will be used as the primary objective quantitative measurement of the effect of this positioning. This article reports on the ongoing development of a simple to use positioning device to facilitate positioning a child or young adult in a series of postures as one aspect of the larger study. This study design requires a pseudo- random series of postural changes, primarily in the saggital plane, by the variation of the relative angle of body segment to body segment as well as to gravity.

BACKGROUND

Related work by Geoff Bardsley, who designed and uses a powered mechanical positioning device for research studies and clinical seating evaluations, has shown the advantages of automating such a device. However, the geometry of his device would require a number of adjustments to achieve each specified posture. A review of local experience in the development and use of MPI and Foam and Plywood Simulators as manually adjustable evaluation tools revealed a similar situation.

Positioning tools, in which a series of adjustments were required to achieve a change from one specified posture to another, were judged to be clinically inefficient for the purpose of our study. Excessive adjustment activities might adversely effect experimental control design.

The positioning device necessary for the study would provide the range of required postures while minimizing adjustments of the system. Furthermore, it would be necessary to isolate the subjects knee flexion, hip flexion, and position in space independent of other adjustments.

METHODOLOGY

Empirical trials with existing positioning devices were used to develop geometrical design specifications for the needed device. These trials with subjects having a range of body builds indicated that the device could reasonably approximate the action of the human hip and knee joint with simple appropriately located pin joints. Such locations would reduce to a minimum the relative motion of a support module to the individual during angular adjustments. Readjustments of back height, thigh length and leg length might then not be required with each change. These empirical trials ratified the contention that a simple pin joint arrangement could work when applied to the range of angular adjustments required. A majority of subjects investigated could be well accommodated by only two hip joint positions and likewise two knee joint positions.

PERFORMANCE SPECIFICATION

The performance specifications for this device were established to allow initial positioning of the patient in neutral posture, manually adjusting for leg length, thigh length, back height and head position. Further adjustments of these should not be required by the clinician during the subsequent independent automated adjustments of knee flexion, hip flexion, and position in space.

The design of an adjustable framework with separate back and seat modules in two size ranges evolved to address the performance standards and size range of subjects.

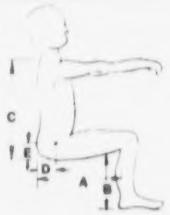
Therapeutic positioning component concepts from the simulators were incorporated into the simple geometry of the support modules. The firm seat component is flat, with adjustable lateral bolsters to keep the pelvis level and midline. The lap belt crosses the pelvis just below the anterior superior illiac spines at a 45° angle to provide a downward, posterior force maintaining pelvic positioning. A removable pommel provides LE channelling in a neutral position. Foot supports place the ankle in a 90° position with 45° foot straps. This encourages pressure to be taken on the heel rather than the ball of the foot. The firm back component consists of a flat surface with adjustable thoracic supports, a chest panel, and removable head supports.

CURRENT STATUS

Positioning trials with two different sized subjects confirmed the basic utility of this positioning device. Further work is required to smooth the action of the hydraulic adjustments enough for the purposes of the study. Additional positioning trials to quantify the relative motion of back and seat modules for different sized subjects are required.

TECHNICAL SUMMARY/ADJUSTMENT SEQUENCE

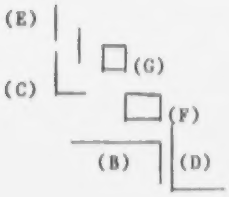
1. Record anthropometric data
    - a. Thigh length
    - b. Leg length
    - c. Back height (C7)
    - d. Back to hip pivot
    - e. Seat to hip pivot



2. Determine seat and back module
    - a. If dimension E is equal to or greater than 3" use thin seat module
    - b. If dimension D is equal to or greater than 3" use thin back module

(Knee pivot to hip pivot is assumed to be proportional to the size of the body)

3. Adjustment of chair to anthropometric data
    - a. set all angular adjustments to 90°
    - b. insert proper back and seat module
    - c. thigh length cylinder
    - d. back height slide tubes
    - e. leg length slide tubes
    - f. neck collar/headrest slide bar



4. Fine adjustment of chair to patient
    - a. position patient using appropriate restraints
        1. seat belt at 45° angle
        2. chest panel with 'H' strap pattern
        3. foot straps at 45° angle
    - b. locate position of thoracic pads (G)
    - c. locate position of L.E. pads (F)
    - d. Check for proper positioning and make any fine adjustments required.

5. Ranges of adjustments/angles (in./degrees)
    - a. thigh length 7 min. 22 max. (powered)
    - b. back height 10 min. 20 max.
    - c. leg length 5 min. 15 1/2 max.
    - d. height from floor 30 min. 45 max. (powered)
    - e. Thoracic pads width 7 min. 14 max.
    - f. LE pads width 6 min. 14 max.
    - g. back flexion angle 25° extension angle 40° (powered)
    - h. hip flexion 50° extension 20° (powered)
    - i. knee flexion 30° extension 90° (powered)
    - j. foot flexion 20° extension 20°
    - k. attitude in space 50° back from horizontal, 15° forward from horizontal (powered)

6. Description of controls
    - a. Powered adjustments - all powered adjustements are accessed thru a central control panel. A master switch must be held with one hand in order to operate any one of six functions. Each switch is a double pole double throw switch (i.e. switch #1 in the up position increases thigh length, down decreases thigh length).

      Power for these adjustments is supplied by a hydraulic power unit located in the base of the chair. The base of the control panel houses the relays, valves, and regulators required for each movement.
    - b. Manual adjustments - manual adjustments are used on those adjustments that are set to anthropometric data and are not changed during the data collection portion of the EMG test. These adjustments are slide tube type with locking knobs. The foot flexion - extension angle adjustment is a toothed ratchet with locking knobs; this adjustment is the only adjustment that has set intervals (4°).

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THREE POSTURAL POSITIONING DEVICES

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ABSTRACT - This paper presents postural positioning devices for use in treating patients with severe skeletal deformities in supine and side lying positions. It describes design construction,fitting and application of the devices. The results of daily use in a residential institution are given.

RÉSUMÉ - L'article suivant à l'aide de photos, démontre des exemples utilisés pour positionner les patients qui souffrent de déformiteés squelettique. Nous décrivons la façon de fabrication, l'ajustement et l'application de ces appareils. Ainsi vous trouverez les résultats de l'usage quotidien de ces appareils dans notre institution résidentiel.

INTRODUCTION

The St. Amant Centre is a residential training facility currently housing 275 multiple handicapped residents. Of these, 75 to 80% have severe skeletal contractures which hampers comfortable positioning and provision of care. It is necessary to be aggressive with the deformities both surgically and orthoticly. From a positioning point of view, several positioning devices have been developed to function independently and in conjunction with surgery to reduce the affects of these deformities.

SIDE LYING DOUBLE C BLOCK

PROBLEM

Increased extensor tonus makes it difficult to properly position a child in a straight side lying block. The arched position interferes with respiration, and can cause choking episodes in some cases. It also interferes with acquiring proper rest.

SOLUTION

The double "C" block was developed to flex the child's head, trunk, hips and knees incorporating an abduction block, if required. Using it, we are able to control a good portion of the extensor tone and allow the child to be more comfortably positioned.

The smaller recessed curve accommodates the head position. It is custom fitted to suit each client. It has several benefits, namely, accommodating the fixed position of the head, facilitating breathing,or reducing cervical arching. The double C and single C side lying blocks are usually made reversible so that the client's position can be alternated from side-to-side.

CONSTRUCTION

The main block is custom cut from a full body tracing. Polyurathane foam is used in conjunction with other types. For example, styrofoam is used in areas where greater density is required. Two plywood bases cover the top and bottom of foam. Tee nuts are attached to these to mount belts. Upholstery could be cloth or vinyl. The two sets of restraining straps include velcro, D rings and mounting bolts. These are positioned so that they restrain under chest and pelvis.

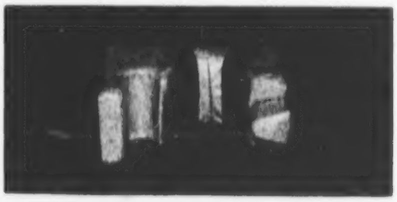

Figure A. SIDE LYING DOUBLE C BLOCK

RESULTS

The block is effective for most children with extensor tonus, allowing them to be positioned comfortably in side lying. Proper placement of the patient in the block, and of the straps around the chest and pelvis area is necessary to maintain the child in the desired position. For those with actual contractures of back extensor muscles, this treatment is not totally effective.

SUPINE HIP ABDUCTION BLOCK WITH HIP-KNEE FLEXION INCORPORTATED

PROBLEM

Many multi-handicapped children with spasticity have increased tone in the hip adductors and ilio-psoas. The pull of these muscles, over time, results in hip dislocation, pelvic obliquity, and scoliosis.

There were several incidences of recurring dislocation following surgical intervention, whether by osteotomy or soft tissue release, due to inadequate positioning of the hips following surgery. The problem was how to maintain the new hip position over time.

SOLUTION

A hip abduction block was developed for the child to use when in the supine position. Enough abduction is built into the block to maintain a reasonable degree of abduction, whether as a presurgical conservative treatment method or as a post-surgical method to maintain hip abduction gained through surgery. Hip-knee flexion wedges were added along with restraining straps to maintain the legs in a comfortable position.

CONSTRUCTION

The supine positioning block is fabricated from a series of materials. The main base is A.B.S. plastic including all mounting holes and carrying handles. Two knee flexion wedges consist of plywood bases, T-nuts, styrofoam or polyurathane foam pads. They are upholstered with terry cloth or vinyl, sewn, glued, stapled and mounted on the A.B.S. main base. The abduction block is fabricated from a plywood base, polyurathane foam, T-nuts, and glue. It is upholstered with terry cloth or vinyl and is mounted with countersinked bolts onto the main A.B.S. base. Two sets of restraining straps are added on at thigh and ankle. These straps are made up of 1" or 2" wide nylon restraining straps, velcro and metal D rings, and are mounted at the large centre block base.

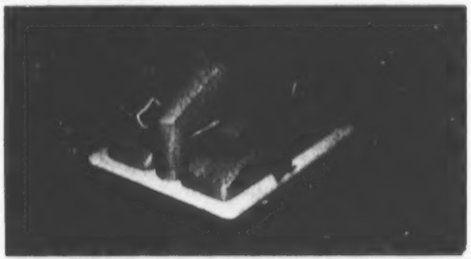

Figure B. SUPINE HIP ABDUCTION BLOCK WITH HIP-KNEE FLEXION INCORPORATED

RESULTS

As a pre-surgical conservative method of treatment for hip dislocation, the abduction block is moderately successful in maintaining a functional degree of hip abduction. By function I refer to such criteria as ease of diapering by staff, painless joint, and comfortable seating.

Over the long term, most hips dislocate due to spasticity. Surgical intervention may be necessary if the aforementioned criteria are interfered with.

Following good reduction of the dislocated joint, proper management through the use of the abduction block has proven to be useful in maintaining a functional range of movement.

SIDE LYING "H" BLOCK

PROBLEM

The concern is to maintain hip abduction (for the same reason as the supine hip abduction block) when the child is in side lying. The side lying position contributes to hip dislocation because of gravity pulling the top leg into adduction.

SOLUTION

A padded foam block with channels to accommodate legs was devised to fit between the child's legs to maintain the hip at neutral or slight abduction when the child is in side lying. Leg channels on the block also keep the child's legs from scissoring.

There are two sets of restraining straps mounted across the leg channels to retain the legs in the desired position. The block is generally used in conjunction with a long bed rail block.

CONSTRUCTION

The reversible "H" block is fabricated from polyurathane foam cut to the desired shape Four pieces of plywood are used at the top and bottom of the H block to give it rigidity and to be used as bases for mounting restraining straps made up of velcro and D rings, two on each leg. The entire block is upholstered with a removable vinyl or cloth bag. The distal end of the block has a recess to accommodate the feet.

Figure C. SIDE LYING "H" BLOCK

RESULTS

The "H" block is quite effective in maintaining the hip in a desirable and restful position while in side lying. Problems may result if the child is not properly positioned or if the child's movements puts the block out of place. Because, in any institutional setting, management is a problem and an assured fit is crucial to the effectiveness of this device, it must be designed and fitted so that it is obvious if the device is properly fitted.

Use of block will not prevent dislocation on the long term; however, it reduces some on short term. As child grows additions, modifications and alterations are required.

ACKNOWLEDGEMENT

The author wishes to acknowledge Sister Bertha Baumann, Executive Director of St. Amant Centre, and the Physical Medicine Department for their support in presenting this manuscript.

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THE POSITIONER DESK FOR YOUNG PHYSICALLY DISABLED CHILDREN

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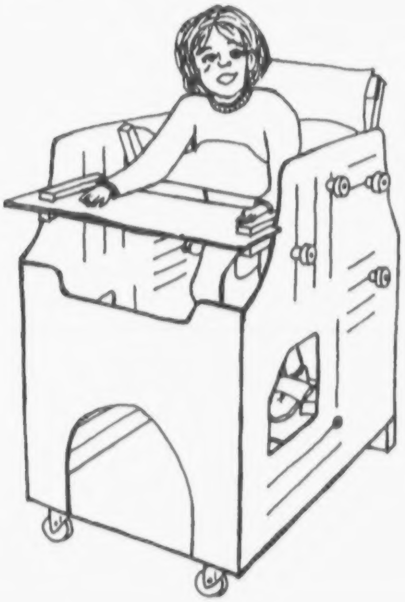
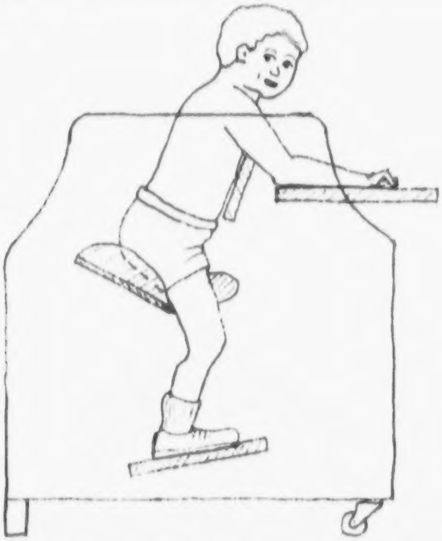
ABSTRACT - An alternative positioning device has been designed for preschool-aged children to help them develop balance and postural skills while weightbearing intermittently.

RÉSUMÉ - On a conçu un nouveau dispositif de positionnement pour des enfants d'âge préscolaire qui les aideront à développer leurs équilibres et à améliorer leurs positions tout en soutenant leurs poids de façon intermittente.

Adaptive Design Services is a regional adaptive equipment program funded by the Massachusetts Department of Mental Health to serve the needs of the severely developmentally disabled throughout the western part of the state. The program focuses on service delivery, particularly in the areas of positioning and mobility, for those clients whose requirements are beyond the effectiveness of commercially available equipment. Though the program remains based at the Belchertown State School, approximately half of the clients served live in various settings out in the community. This has given us the opportunity to work with young children in early intervention programs for whom there is the greatest hope of optimizing function and preventing the deformities seen in older institutionalized clients. In response to referrals received from the therapists working in these programs, we have been looking at the growing selection of pediatric therapy equipment and specialized furniture and have been attempting to address particular therapeutic considerations and segments of the population for which this commercial equipment is inappropriate or inadequate. Our approach has been to work closely with the families, teachers, and others involved with the client in order to integrate everyone's needs and expectations and develop devices which are compatible with home and school environments, therapeutic and educational goals, and daily activities. We feel that the equipment must be able to grow and adjust as the child matures and responds to good positioning, and it must fit well into a child-sized environment and allow interaction with peers. The use of simple, low-cost materials can make it easier to experiment with different designs and features for each child, as well as more available to those who need the equipment.



It was with these concerns in mind that the design for the positioner desk evolved over the past year and a half. We had identified a need for an alternative to commercially available seating and standing devices for children under the age of six or seven in which we could incorporate some new positioning ideas we were exploring. Experimentation with the Norwegian Balans chairs made us aware of the potential of a partial sitting posture with an open hip angle. These chair designs were based on Keegan's and Mandal's studies of low back pain patients showing that the typical seated posture with the hips flexed to 90° tilts the pelvis posteriorly, flattening the lumbar lordosis and increasing intradiscal pressure. Mandal introduced the concept of a seat with a forward tilt to bring hip flexion closer to the resting or unloaded position of 135°, maintaining the normal lumbar curve seen in standing and allowing the spine to balance over one's center of gravity with less muscular distraction and compensation. The first tilt chair designs were basically variations of a typing or office chair with a negative seat angle; one perched on the chair with feet flat on the floor to bear some weight and to keep from slipping forward. The Balans chairs, however, combined the tilted seat with knee supports, positioning one with knees flexed more than 90° and distributing weight between the buttocks and the knees and lower legs. This knee weightbearing initially seemed attractive as a way of providing the orthopedic benefits of weightbearing through the hips with greater stability for the child with abnormal tone or inadequate standing balance, but without strapping him into the static position of a prone or supine board. The seat angle emerged as the more crucial factor in positioning these children, however, because of its influence on the degree of pelvic tilt and thus on muscle tone throughout the body. By changing the tilt of the pelvis we were able to find positions in which the child's flexor and extensor tone was relatively balanced or equalized, enabling him to sit with a minimum of external support and to begin developing and using immature righting and equilibrium reactions.



The positioner desk is basically a three-sided box made of composition board with interchangeable supports which can be added and arranged to suit each child. This modular system of components developed as we worked with a dozen children and saw similarities and differences in their needs. The tractor seat, sculpted of foam on a plywood panel, is designed to cradle the child's buttocks and hold the legs abducted, with a nonslip removeable cover and a nylon or elastic seatbelt. The footboard can be equipped with shoeholders and ankle straps to control rotation of the feet. A knee pad can be added for more control of rotation or abduction as well as for preventing too much knee flexion. Weightbearing on the feet has worked out better than kneeling, even for the child with a positive supporting reaction or hypersensitive feet, as the child is able to stand intermittently and then relax back to sitting as desired. The angle and height of the laptray influence upper body tone, both through weightbearing on the forearms or elbows and through the effect of visual orientation to the work surface on the position of the head and neck. For those children with less trunk control, a chest pad has been useful, sometimes with lateral supports. Added safety and control of extensor thrust patterns have been provided by a strap behind the child or by specifically placed back, neck, or head rests.

The components are all adjustable in height, angle, and their relationship to each other through the use of slots in the frame and knobs or bolts on each component. The hardware evolved to allow adjustments to be made easily with the child seated in the positioner, enabling one to change his posture and freedom of movement to find positions which inhibit abnormal tone and reflexes and facilitate normal movement patterns. Used properly, we've had good success in promoting lower extremity weightbearing and -shifting and in developing trunk strength and balance and upper extremity skills. Careful evaluation and monitoring by knowledgeable therapists is necessary to ensure that the child is provided with the appropriate amount of support to control tone and make him feel safe and comfortable, but to allow enought movement that his development is enhanced through his use of the positioner. It is this dynamic feature of allowing the child to rise to standing and then relax back to sitting within a controllable range of movement that distinguishes the positioner desk from the static prone or supine standing devices generally used to provide alternative positioning and which may allow children to use them comfortably for longer periods of time. It also fits into the child's environment like a normal piece of furniture. It is a freestanding unit which can be moved about the classroom or home, easily approachable by other children and adaptable for a variety of activities. We encourage parents to paint them and select upholstery fabrics which fit into their decor and make them more personal for the children.

We plan to continue building, evaluating, and refining the positioner desk as we are able to for our client population, but there have been enough requests for them from therapists working with young children that we've begun looking into ways to have them more widely available. While adoption of the design by a commercial manufacturer would be gratifying, we have concerns about maintaining the integrity of the design and about lack of proper supervision of its prescription and use. The same features which allow for its easy adjustability and adaptation to the particular postural needs of the child also allow for its misuse. As with any adaptive equipment, safe and effective employment relies upon the expertise and management of those working with the child, as well as the realization of the role which equipment plays within a total program of developmental therapy.

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Illustrations: Carl Johnson
This project was developed with the support and assistance of the entire Adaptive Design Services staff.

SECOND GENERATION VINYL VACUUM FORMING MACHINE

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ABSTRACT - The ongoing development of a second generation vinyl vacuum forming machine for specialized seat covering is described. Technical improvements to the machine, reporting on new materials and adhesives are discussed.

RÉSUMÉ - Le présent rapport porte sur la mise au point d'une machine de deuxième génération pour la pose de revêtements en vinyl sur des sièges spécialisés par la technique du vide. On examine les améliorations techniques apportées à la machine ainsi que de nouveaux matériaux et adhésifs.

OBJECTIVE

The objective of this project has been to make commercially available a seat covering vinyl vacuum forming machine for facilities where custom seats are being manufactured.

BACKGROUND

The background to this technique has been covered in a previous article.(1) A second generation prototype of the original device has been functioning in The University of Tennessee Rehabilitation Engineering Program Client Services Department for approximately one year. Over the period of that year, various improvements have been made both to the equipment and to the techniques used for pulling the vinyl along with development in techniques and use of new materials. It consists of a box base used as the mold and frame support and an infrared heat source. The box base is also used to mount a control system consisting of timer and switch, a vacuum pump, a variable vacuum control and a Destaco clamp for locking the frame.

The changes from this basic concept have been simple and have been related to positions of controls and also the addition of an aluminum screen reflector system which allows the vinyl to be brought up to a higher working temperature than was previously possible. The reason for raising temperature of the vinyl was to allow the material to reach a higher level of plasticity for the pulling process. This is helping with a problem of vinyl pulling away from the substructure of the seat after a time. Using these higher operating temperatures, the machine has been able to pull draws of up to 8½" on a regular basis. The total time from start to finish of the operation including loading the frame is typically in the order of fifteen minutes.

VINYLS AND ADHESIVES

The vinyls used in the past year have been supplied by the manufacturers Mobern (Black Vac 40) and Uniroyal (Naugaform 0.065" thick), also tried has been a Uniroyal product part number S9949A, dark royal blue, which is a vacuum formable vinyl

Test #	Heat Source		Adhesive	Vinyl	Pull Away
	Direct	With Reflector			
1	x		Mactac 1200	Morden 40	1 3/8"
2	x		Mactac 1022	Morden 40	2 9/16"
3	x		3M 74	Morden 40	2 1/2"
4	x		Car Top Glue	Morden 40	2 1/4"
5	x		Goodyear Plio Bond	Morden 40	2 11/16"
6	x		3M 74	Uniroyal	1 7/8"
7	x		3M 76	S9949A	1 5/8"
8	x		3M 90	S9949A	1 7/8"
9		x	None	S9949A	1 1/16"

NOTE: The Pull Away column was an arbitrary measurement taken by placing a builders level across the trough of the "seat mold" and measuring the distance from the level surface it was sitting on minus the nominal material thickness of 1 1/2". Therefore, the lower the figure the better the results.

Figure 1.

with a self absorbant fabric surface.

The Uniroyal S9949A has an exciting potential as a seating material in this field, since this material is currently being developed for the car seat market, where long periods of sitting are common and customer comfort is of great importance. In service use, we are restricted to the use of the commercially available Mobern and Naugaform. Tests were carried out using specially constructed "seat molds" of the following dimensions and materials: plywood base, size 9½" by 18" by ½". The structural foam used was Rogers foam cut into longitudinal wedges approximately 3" wide at the bottom, 1½" wide at the top, and 3" high. These were covered with one inch polyfoam. The adhesive used at this joint was the aerosol 3M 74 foam adhesive. Five tests were carried out using the Mobern vinyl and four tests using the Uniroyal S9949A material. Refer to Figure 1 for test results.

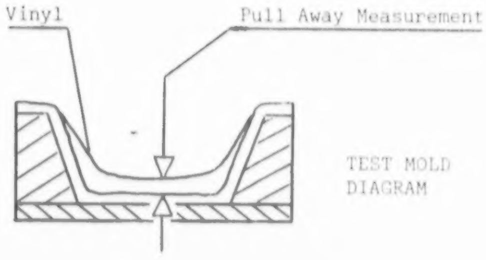
FORMING UVEX, POLYSTYRENE AND ALIPLAST

It was pointed out at the last meeting(2) that this machine might have the potential of pulling thin Uvex sheets as used in the manufacture of face masks in the treatment of severely burned patients. In order to test this theory, plaster positives of the faces of three patients from Vancouver General Hospital were sent to UTREP for testing. A simple wooden double sided frame was made which enabled a piece of Uvex approximately fourteen inches square to be mounted onto the frame of the vacuum forming machine in the normal way. Side aluminum reflectors were used as was a parallel reflector which reflected heat back from the surface of the polystyrene. The Uvex reached working temperature in approximately six minutes and was pulled over the face molds with no difficulty in about fifteen minutes for the whole process. In the same way, polystyrene and Aliplast have been vacuum formed on the machine.

CONCLUSIONS

1. It became apparent towards the end of the testing process that one variable which was difficult to control in this series of experiments was the thickness of the material used which varied and the temperature which the material reached during the process. The best results have been obtained using the Uniroyal S9949A material reversing the material so that the black side of the material was heated by the infrared heat source and then pulling this down over the mold with no adhesive. After seven weeks, the material still conforms closely to the contour of the "seat mold". The technique used here was to construct aluminum reflectors along the sides of the infrared heat source and reflecting panel parallel to the surface of the vinyl which reflected any radiated heat back to the vinyl. Heating times were short, in the order of six minutes. At this stage it became obvious that our main problem was not so much with the type of adhesive but with the temperatures being reached with the machine. Vacuum formable vinyl machines being constructed now are incorporating the side aluminum reflectors as a standard feature, the aluminum reflectors are now available as a retrofit for existing machines. Because of this experience we are staying with the adhesive which has been used for some time because of its convenience, the 3M 74. Other approaches have been to use the thin film of pure adhesive which is applied to the vinyl before heating as a sheet. Used here was Mactac 1200 and Mactac 1F 1022. Also used in the test was a locally available contact cement for adhering vinyl tops to the roofs of cars, another type was Goodyear Pliobond which is applied by brush and 3M 90 and 3M 76, both aerosol adhesives. It is felt that for use with the Uniroyal S9949A material that either the 3M 76 or the 3M 90 would be the most suitable adhesive but further testing is required before a conclusion can be reached.

2. The current design of vinyl vacuum forming machine is also suited to the pulling of 1/16" thick Uvex and ¼" Aliplast sheets approximately fourteen inches square, larger sizes of sheets and thicker sheets might be appropriate for this machine although this has not yet been tested at the time of writing



TEST MOLD
DIAGRAM

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THE MERU SHAPEABLE MATRIX SUPPORT SURFACE FOR CHILDREN AND ADULTS

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ABSTRACT - A new generation of mechanically adjustable surfaces has been developed which provides a means for fine control of surface shape. The high shape resolution enables intimate fit and fine pressure control in custom formed seat and bed surfaces.

RÉSUMÉ - Une nouvelle génération de surfaces réglables par des moyens mécaniques a été mise au point enchainement; elle fournit le moyen de réaliser un réglage fin de la forme d'une surface. La résolution élevée des formes permet un ajustage précis et un réglage fin de la pression pour les surfaces de sièges et de lits personnalisés.

Introduction

Shapeable Matrices are mechanically adjustable surfaces composed of finite components. The concept of applying these adjustable surfaces to seating was initiated clinically by Cousins in 1978 (1). This system and the one following it (2) demonstrated the applicability of Shapeable Matrices to seating problems. 55 of these first systems were fit to Cerebral Palsied children. They demonstrated the advantages of having a seating system composed of mass producable components that could form a custom sitting surface. The inherent adjustable nature of the matrices enabled them to change to accommodate growth and development of the children. Technical difficulties were insufficient strength and a limitation in the intimacy of fit to asymmetrical shapes.

In development of the third Shapeable Matrix system for seating at the Bioengineering Centre, University College London (3), Cousins addressed the problem of strength. This system is being marketed successfully in Great Britian and parts of Europe with wide application to principally children. At the Medical Engineering Resource Unit we have applied the concepts of Shapeable Matrices to the adult population in need of special seating. A new generation of mechanically adjustable surfaces has been developed which provides divergence between individual elements. This has provided a means for fine control of surface shape enabling intimate fit and fine pressure control in custom formed seat and bed surfaces.

Design

The matrix is composed of nodes interlocked by beam pairs, (figure 1). Surface shape is controlled by appropriate adjustment of beam lengths. Typically, most seat matrices contain 150 to 250 nodes and 400 to 600 beams. The nodes are cylindrical with 8 slots, (4 on each end), into which the beams insert. The beams are flexable rods with incremental extensions to hold them securely in place. There are 7 beam types.

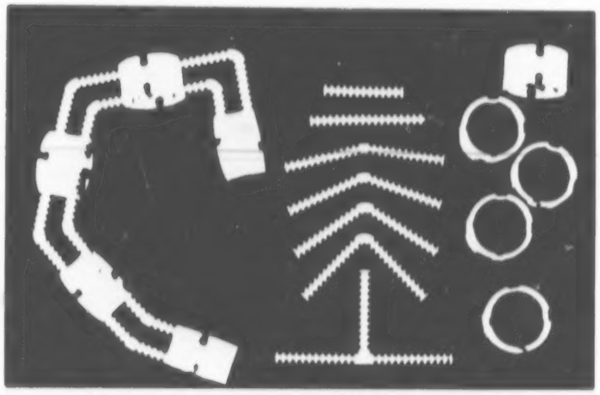

Figure 1: Nodes and beams; separate and combined.

Injection moulded surfacing elements attach to each node to provide a continuous surface for supporting foam padding. Since the seat is custom shaped to the individual patient, very little padding is necessary. Though various paddings have been used, they are typically 1/2 or 5/8ths inches thick and of medium to hard stiffness. The foam is attached by an extruded vinyl component which also finishes the edge of the matrix. Most seats have a cotton cover that can be easily removed for cleaning.

The seat frame reinforces the matrix and orients it relative to gravity. The frame hinges in 5 degree increments, about an approximation of the hip joint axis in the sagittal plane. Drop hooks are used to interface with standard wheelchairs and a highchair frame.

Headrests can be made of matrix components integral with the seat back or commercially available headrests can be interfaced to the seat frame.

Fitting and Assembly

Following a thorough function assessment, dimensional data of the patient and the wheelchair into which the seat will insert is taken. This requires only 7 measurements for fairly symmetrical clients. The small number of measurements is possible because the matrix can be adjusted easily after the seat has been assessed with the client in it. Clients with severe deformities require more measurements to describe their individual requirements.

System back and system seat matrices are assembled to patient dimensions. Separation of the matrix into two portions eases assembly and covering with foam and fabric and permits hip flexion to be adjusted after the seat has been finished. In the majority of cases, the seat matrix is formed with an anti-thrust block to help maintain pelvic stability. The lateral supports are made to fit snug to increase reproducability of positioning. The matrices are shaped to avoid pressure in the areas of the greater trochanter, sacrum, and gluteal cleft. The matrices are covered with surfacing elements, foam and edging before attachment to the frame. 4 to 8 hours are required for completion of a seat by a skilled technician. The least symmetrical seats require the greatest amount of time to assemble.

When a client tries a seat, pressure measurements are taken between the client and the seat in critical areas and the patient's skin is checked for redness. If necessary, changes are made to the seat to modify pressure distribution.

Clinical Applications

Clinical applications have not been a priority during development of the system. As of December 1983, 20 seat or bed inserts have been fitted to individuals in the Vancouver area for design testing and determination of the system's limits.

Nine seat inserts were fit to adults with sitting problems secondary to; diabetes, quadriplegia, hemiplegia, arthritis, multiple sclerosis, and old age. All the adults required a combination of both postural control and pressure management. Common postural problems were structural kyphoses, minor scoliosis, knee and hip contractures, oblique or rotated pelvises, and hypotonia. Pressure management was by a custom contoured seat matrix or, as in 2 cases, the use of commercial seat cushions. Client weights ranged from 40 kilograms to 102 kilograms.

Eight seat inserts were fit to children with cerebral palsy and muscular dystrophy. The children presented a wide range of postural control problems. Most had spinal and hip deformities; all the cerebral palsy children required control of abnormal reflex activity. For one severely involved muscular dystrophy child, it was not possible to provide the necessary support. He could not be supported partially reclined without surpassing his comfort tolerance. This patient ended up totally reclined in a different system.

The children's and adult's seats functioned well. Technical problems highlighted by the clinical trials were resolved by the development process. The only remaining limitation of the system is adequate stabilization of the pelvis in the sagittal plane for clients with structural kyphoses and forced hip extension. This problem is universal to specialized seating devices.

Four bed inserts were provided to adults. Three of these clients had persistent acute ulcers. They were supported by the inserts on the body surface of the ulcer with complete pressure relief in their affected areas. The devices were used on an intermittent basis to enable the clients to lie in various positions. One of these inserts also served to serially extend knees with tight musculature. The fourth bed insert was for a person with severe spinal deformity and hip and knee flexion contractures. The insert supported him while lying supine.

Costs

Seat costs range from $175 to $225 for components plus the 4 to 8 hours required for assembly.

It should be noted that these costs are for the first time a seat is assembled. The adjustable nature of the seats permits them to be altered rather than replaced as the users grow and develop. This greatly reduces the long term cost of the seats. As a result, changes to accommodate for growth and development are made on average, at approximately 6 month intervals.

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A PRACTICAL METHOD FOR DATA COLLECTION FOR SEATING/MOBILITY DESIGN

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ABSTRACT - A simple, quick method to collect meaningful anthropometric data will allow the development of better tools for the design of seating and mobility systems.

RÉSUMÉ - Une méthode simple et rapide pour obtenir des données anthropométriques utiles fournira de meilleurs outils pour concevoir des systèmes pour asseoir et déplacer les handicapés.

INTRODUCTION

A recognition of the need for postural support, function, and mobility devices other than the traditional wheelchair has stimulated applied research and device development. The last several years have seen an increasing involvement of the commercial sector in the design and marketing of products that address some of these needs. Review of the literature, however, finds that anthropometric data required for knowledgeable design for specific populations of nonambulatory individuals does not exist, and what data does exist is not in a form usable by designers of seating and mobility systems. The University of Tennessee Rehabilitation Engineering Program (UTREP) with sponsorship from the University of Virginia Rehabilitation Engineering Program is addressing this and related problems for a population of children and young adults with Cerebral Palsy. The development of a simple method to collect meaningful anthropometric data, and its use in the development of specific design tools for designers of both seating and mobility systems is one such project.

Practically, how is one to collect anthropometric data that contains the information that is usable for seating system designs? If one assumes that a subjectively good seated posture for a particular individual can be determined, then measurements that relate that individual's size and shape to posture would be useful for such design. However, measurements taken without respect or relationship to a subjectively good seated posture may contain accurate information that does not address the issue of seated postural design. However precise, such data may have limited usefulness for our purpose, the design of seating and mobility devices.

Clinicians in our service program use seating simulators as part of their client evaluation process to determine good seated posture. If additional requirements to collect research data are imposed on their busy schedules, the method must be simple, and require a minimum amount of time from the overall evaluation process. The method must also be acceptable to our clients, both from the standpoint of technique and time.

THE METHOD

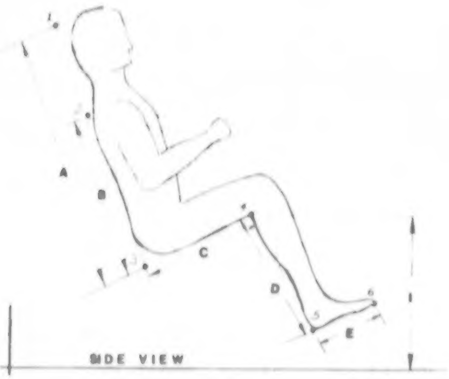
A method has been developed to collect useful data within a five minute time frame. The procedure requires nine linear measurements and four angular measurements. The combination of a ruler (for linear measurement) and a spirit level (for angular measurement) into one device allow for such rapid data collection. Length markers, which clip onto the ruler, are keyed to the data record form. The four angular measurements must be read in place, but the markers allow the linear measurements to be marked and then read and recorded as a group, a further time saver.

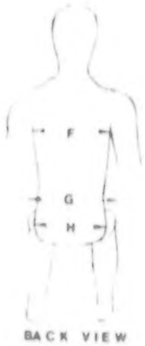
The collection of such data from a number of individuals will serve to develop a data base which can be stored by and manipulated with economical electronic spreadsheet software and a microcomputer.

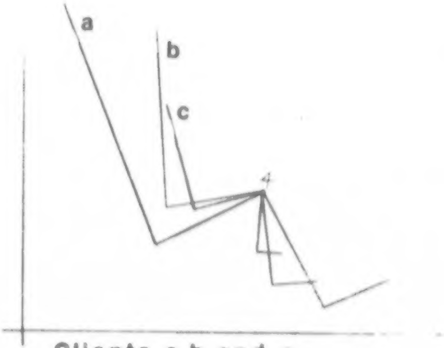
The spreadsheet transforms this data into the three orthogonal components of a position vector which relates the points of measurement to some arbitrary origin. Once these positional vectors have been determined, data analysis can be performed. For example, with information on a series of individuals in this format, it is technically simple to superimpose this data such that each individual had a common knee joint locus. This overlay of data allows designers to readily visualize the implication of a

DATA FORM

		INCHES	DEGREES
A.	Seated Height	______	
B.	Shoulder Height/Angle	______	______
C.	Thigh Length/Angle	______	______
D.	Leg Length/Angle	______	______
E.	Foot Length/Angle	______	______
F.	Trunk Width	______	
G.	Knee Width	______	
H.	Hip Width	______	
I.	Knee Height	______	







Clients a,b,and c

Point #4 common

seating design that provides a change in attitude of thigh to gravity by means of a pivot at the anterior portion of the seat surface.

With such a data base, the designer can view the angular and linear data independently and construct hypothetical seating subjects who require the extremes of linear and angular adjustments. The most common measurements can be identified to facilitate economical modular approaches to seating design. The designer of mobility bases can identify the collective space requirements of the population under study, and thus avoid design which limits its wide application.

LIMITATIONS

Data from a small population will not provide sufficient information for statistical purposes. This lack could be addressed by use of the subjective clinical experience of individuals who have worked with these populations. The best speculation of clinicians with experience could help to produce at least a pseudo distribution curve to prevent imposing upon the designer those extremes of adjustments that would be little used in the real world. Such a data collection method does not address those factors of importance such as contour, firmness, resiliency, texture, heat transfer, etc., that are so vital to the success and functional outcome of a seating system. However, such data taken for a specific functional group of individuals will provide improved design tools.

ACKNOWLEDGEMENT

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THE EFFECTS OF THE NECK AND TRUNK FUNCTIONAL SUPPORT ON SPASTICITY IN CEREBRAL PALSIED CHILDREN

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ABSTRACT - Hypotonocity of the trunk (or neck and trunk) appears to influence the muscle recruitment pattern of cerebral palsied children. A functional support to their trunk (or neck and trunk) seems to alter the pathological movement patterns, according to this study.

RÉSUMÉ - L'hypotonie de la nugue et/ou de tronc semble influencer la séquence des mouvements musculaires chez les enfants atteints d'infirmite du moteur cérébral. Suite à cette recherche l'application d'un support fonctionnel à la nugue et/ou tronc parait modifier l'enchaînement des mouvements pathologiques.

Introduction:

Three sequential phases have been consistently observed in the development of cerebral palsied children:

a) Flaccidity of neck and trunk musculature in infancy. (1) Later, the tone in the neck usually improves substantilly during the first eighteen months to two years (with the exception of severely involved children), whereas the trunk improves only marginally and remains hypotonic except when they make a volutary effort to stabilize themselves proximally. (2)
b) There are individual variations in the development of spasticity, however its onset is usually before the age of two years in cerebral palsied children. (3) Spasticity mainly develops in the large muscles of the extremities and pelvic and shoulder girdles.
c) A residual effect is the persistance of tonal imbalance between the hypotonic trunk (or trunk and neck) and the spastic extremities throughout their lives. (2)

The majority of cerebral palsied children (with the exception of those who are severely handicapped mentally and physically) explore to learn and attempt to attain antigravity postures such as crawling, pulling up to sit, standing, etc. It is an innate behaviour for any child to attempt to achieve antigravity postures and maintain them. The children with cerebral palsy are not exceptions. These children will try to come to antigravity positions with whatever motor abilities they possess. The result is obvious: the poorly functioning trunk is assisted by recruitment of the muscles of the extremities to achieve maximum safety in antigravity positions, and learning of the functions of the extremities, such as hand functions and ambulation, suffers severe set-backs. At the same time, they do not make expected progress in achieving antigravity positions, due to lack of balance. Their efforts invariably lead to muscle recruitment patterns referred to in the literature as "abnormal postural reflex activity". (4) These recruitment patterns are elicited whenever these children try to roll, crawl or sit. Such frequent recruitment of spastic muscles in the extremities increases the tone in them, perhaps due to the "position memory". (5) Whenever safety is threatened due to loss of balance, these children contract towards the midpoint of the body and totally flex themselves to reduce injuries resulting from the fall, especially to the head and face. This also increases tone in the involved muscle groups. Learning is disrupted because when these children attempt a motor activity, they must also protect themselves from loss of balance. This pattern of movement facilitates increased spasticity in the frequently recruited muscle groups, as compared to groups which are not recruited often, and also leads to contractures. The majority of cerebral palsied children with quadruplegia require surgical intervention to release tight hip adductors, hamstrings and/or heelcords before the age of five years. (2)

Aims of the Orthosis:

A functional support for the neck and trunk of cerebral palsied children seems to be effective in minimizing the tonal imbalance if it meets the following criteria:

The trunk of the cerebral palsied child is basically hypotonic. Hence in sitting position, abdominal musculature collapses under the weight of the head and chest and the floating ribs almost rest on the iliac crests. The hypotonia of abdominal muscles usually makes sitting balance precarious. Also, lack of room between the iliac crests and the ribs make trunk rotation impossible. Trunk rotation is important for many motor functions such as standing, walking and positioning upper extremities for fine motor tasks, etc. An effective orthosis should lift the chest by providing support under the floating ribs on either side, which would: i) restore badly needed space between the floating ribs and iliac crests for trunk rotation (2) and ii) preven extreme flexion of the trunk. For these children it is difficult to come to midposition from extreme flexion of the trunk.

Rigid supports usually restrict movements, which is not advisable because motor abilities in these children are already limited. Therefore, air-filled neoprene or nylon bags have been used so the support can be flexible and adjust to the tonal status of the trunk. The back of the neck usually supported along with the trunk, even for those children who are able to right their heads, as shown in Figure I. This primarily helps to achieve better balance, especially in sitting, standing and walking postures. For those children who have a poorly functioning neck, as well as trunk, additional support is provided under the chin.

Construction of Orthosis:

We neither had the expertise nor the financial resources to custom make the type of air-bag required to properly support the trunk and neck of the children who participated in the study. Bicycle inner tubes (2) or air safety jackets were used for this purpose. This system has obvious drawbacks, such as: i) from continuous use the inner tubes deform easily, and ii) the air safety jackets are available in one or two sizes only. Despite the limitations, these supports were capable of partially minimizing the tonal imbalance. The orthosis was made by joining two air safety jackets at the top. They were worn in such a way that one of the jackets will support the back from the occipit to the sacrum and the other supports the trunk in front. Both jackets were tied together on each side. A corduroy vest with abdominal straps was used to provide necessary air pressure under the ribs to support the trunk. The pressure was maintained at 8 to 9 p.s.i., which was gradually reduced as the trunk musculature improved. The lower end of the vest was anchored to the shorts on either side to prevent the air pressure pushing up the air bags away from the waist.

Does the support help to minimize the tonal imbalance? Changes were observed in the motor abilities, indicating that the orthosis does influence the total motor function.

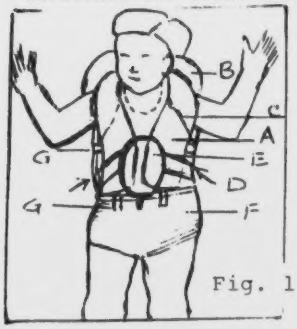

Fig. 1

A - Front-Air Support
B - Back - Air Support
C - Corduroy Vest
D - Abdominal Strap
E - Abdominal Apperture on Vest
F - Shorts
G - Connecting Straps

S.A. is a $4\frac{1}{2}$ year old boy diagnosed with cerebral palsy (spastic quadruplegia) in November, 1980. He has been receiving physiotherapy since April 1981. He was referred for occupational therapy in July 1981 and has been receiving treatment since then. He was seen by an orthopaedic surgeon in October, 1982, who advised adductor releases and heelcord lengthenings due to contractures. We were allowed to try functional support prior to surgery. Use of the functional support commenced in December, 1982 and has been consistently used for at least a couple of hours every day. Subsequent check-ups by the orthopaedic surgeon in March, August and November 1983 revealed marked decrease in adductor spasticity with satisfactory active hip abduction bilaterally. Full dorsiflexion of right ankle has been achieved, but left ankle still has a tendency to tipping toes while walking, though this can be dorsiflexed passively. No surgery has been necessary so far. Other improvements include: - decrease in amount of drooling; - scissoring of lower extremities decreased substantially and - severely involved left hand function has also improved.

Conclusion:

The above clinical observations indicate that the muscle recruitment patterns of cerebral palsied children are related to the hypotonicity in the trunk or the trunk and neck. Although brain lesions are responsible for the spastic status of cerebral palsied children, the rate of increase of spasticity and the development of contractures were related to frequent recruitment of muscles of the extremities to attain antigravity postures and to stabilize themselves. Further development of contractures in cerebral palsied children can be arrested or even reversed in some instances, depending on the circumstances, such as:

1) A recent tendo-muscular contracture which is not accompanied by structural changes in the joints or bones.

2) The support would not be effective unless the child is able to take advantage of it. Hence, the child's cognitive abilities are important.

3) Cooperative and observant parents are essential, if the programme is to succeed. The child should be made to wear the orthosis consistently and the child's way of adapting to it has to be monitored continuously. Also, occasionally someone has to passively stretch severely contracted muscle groups.

At present the functional support is held in place by a series of straps. Further work needs to be done to simplify the present orthosis. Since most cerebral palsied children need the functional support in early infancy, it would be helpful to incorporate it into their garment itself. Also, future research needs to focus on modifying the neck support. With it, one could minimize the tongue thrust, so these children could be fed more easily, resulting in healthier children.

My thanks to Dr. R. D. Beauchamp and Mr. T. M. Paradkar for their help and guidance. Also, I thank Mrs. Cindy Reierson for helping me make this paper presentable.

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BODY ORIENTATION IN SPACE AND TONIC MUSCLE ACTIVITY IN PATIENTS WITH CEREBRAL PALSY

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ABSTRACT - This study was designed to determine whether tonic activity of selected muscles of patients with cerebral palsy changed in response to changes in the orientation of the body in space. Electromyographic (EMG) activity of the low-back extensors, hip adductors, and ankle plantar flexors was monitored when the body was oriented at both 0 and 30 degrees relative to vertical. The results indicate that differences do exist and muscle activity was less at 0 degrees.

RÉSUMÉ - Cette étude a été conçue pour déterminer si l'activité tonique de certains muscles chez des victimes de la paralysie cérébrale changeait en réaction à un changement dans l'orientation du corps dans l'espace. L'activité électromyographique des muscles extenseurs lombaires, adducteurs de la hanche et fléchisseurs plantaires de la cheville a été étudiée lorsque l'orientation du corps était à 0 et 30 degrés par rapport à la verticale. Les résultats indiquent qu'il existe effectivement des différences et que l'activité musculaire est plus faible à 0 degré.

BACKGROUND

Current seating designs and methods of positioning children with neuro-motor deficits are based largely on clinical practices that have been adopted as principles over time. These principles have grown out of treatment techniques which have been adopted for managing young children.

Based largely on the results of subjective clinical observations, several suggestions have been made relative to the seating position of patients with neuromotor deficits. Trefler (4) has indicated that seat backs should be mounted as close to the vertical plane as possible to encourage more normal development and that children should be reclined only when absolutely necessary because once reclined they must struggle against gravity in order to raise their heads to a functional position. It has also been suggested that maintaining the child with the hips flexed results in reduced muscle hyperactivity (Carrington, 1978).

It is highly unlikely that continuing device development will yield significant future improvements in specialized seating and positioning until a deeper understanding of the neuro-motor responses that are induced or inhibited by a seating device can be determined. The differential effects of body segment positioning, location(s) of external force application, non-contact external stimuli and body orientation relative to the vertical are all largely unknown factors in terms of their relative importance towards fostering more normal neuro-motor development and postural control. This suggests the need to address these unknowns through a systematic evaluation and scientific validation of the principles currently employed to position children with neuro-motor deficits. A limited number of studies have been done to address some of these unknowns. In an experiment designed to evaluate the effect of hip flexion angle on tonic myoelectric activity of the hip adductors in cerebral palsy patients it was found that tonic activity was least when the backrest was positioned vertically and the seat surface at 15 degrees from the horizontal giving a hip flexion angle of 75 degrees (Nwaobi, 1983). A most recent study (Nwaobi, et. al, 1983) was conducted to determine whether tonic myoelectric activity of low back extensors of spastic cerebral palsied children changed in response to changes in seating position. It was found that differences existed in the activity of the muscles monitored in the seating positions that were assessed. The results of this study also showed that orientation of the head neck, and body relative to the vertical plane may be as important or perhaps more important than the hip flexion angle in the control of extensor activity.

PURPOSE OF STUDY

This study is designed to measure the tonic myoelectric activity of the low-back extensors, hip adductors and ankle plantar flexors in patients with cerebral palsy in two different body orientations. The purpose of this design is to determine if the tonic activity of these muscles changed in response to changes in the orientation of the body, and if so, which orientation provided the lower level of muscle activity.

PROCEDURES

SUBJECTS

The subjects used for this study consisted of five children and young adults (4 males and 1 female, 6-16 years of age) who have been diagnosed as having Cerebral Palsy. None of the subjects presented with any fixed deformity that prevented them from assuming the seating position used for this study. All the subjects were intelligent and could follow instructions. Informed consent was obtained from the parents of each subject according to the procedures approved the University of Tenessee Institutional Review Board.

INSTRUMENTATION

The positioning device is a multiadjustable seating system with independent hydraulic powered adjustements for knee and hip positions, thigh length, and orientation in space. The data acquisition instrument consists of an eight-channel EMG amplifer system, an analog to digital converter (A/D) (both designed and built by the University of Tennessee Division of Biomedical Instrumentation) and an Apple II computer. The amplifers have a frequency response of 35 HZ to 3KHZ, a gain of 10,000 and integrator time constant of .05 seconds. The A/D has a resolution of 1in 4096. Normal conversion rate used was 120 samples/second.

DATA COLLECTION

A motor point (a point on the surface of the skin over the muscle with the most responses to the same intensity of electrical stimulation) was located on the iliocostalis lumborum, the adductor magnus and on the gastrocnemius muscles of the same side. The skin over the area was cleaned with alcohol and a pair of surface electrodes (1cm diameter Ag-AgU) with electrode paste attached to each point. A ground electrode was attached to the skin over the crest of the tibia. The subject was positioned in the seat such that the hip, knee, and ankle joints were positioned at 90 degrees and the head and neck on the same plane as the trunk. A pommel was positioned to make contact at the distal third of the thigh. The subject was positioned in two orientations relative to the vertical plane (1) 0 orientation in which the head, neck, and trunk were on the vertical plane and (2) 30 degrees in which the head, neck, and trunk were on a plane 30 degrees with the vertical (Fig. 1). The position of the ankle, knee, and hip remained the same at each body orientation. Two samples of EMG activity, each lasting 10 seconds were taken at each orientation selected and were done randomly. A rest period of five minutes was allowed before sampling began after each orientation change. The mean integrated EMG (IEMG) (area under the curve) was obtained for each muscle at each orientation.

RESULTS

The mean IEMG for the lumbar extensors for all five subjects at the 0 degree orientation was 2.9μV.S and 4.8 at 30 degrees (Table 1). For the hip adductor, mean IEMG at 0 degree orientation was 3.9μV.S and 8.3μV.S at 30 degrees. Mean IEMGs of 3.5 and 5.1 were obtained at 0 and 30 degrees of body orientation respectively for the ankle plantar flexors.

The trend is that EMG activity increases as body orientation changes from the upright orientation, 0 degree, to a reclined orientation, 30 degrees (Fig. 2). It was also noted that the number of EMG bursts representing bursts of athetotic activity also increased in the 30 degrees orientation on one subject who presented with athetosis.

DISCUSSION AND CONCLUSION

The results of this study indicate that the activity of the muscles selected was affected by changes in the orientation of the body, tonic activity being less at the upright orientation. The extent and the significance of the difference in the intensity of muscle activity at both orientations is difficult to predict due to the limited sample size. The results of this study has implications for the design and use of seating systems for patients with neuro-motor involvement. However, this is a pilot study and caution should be exercised in the interpretation and use of the results.

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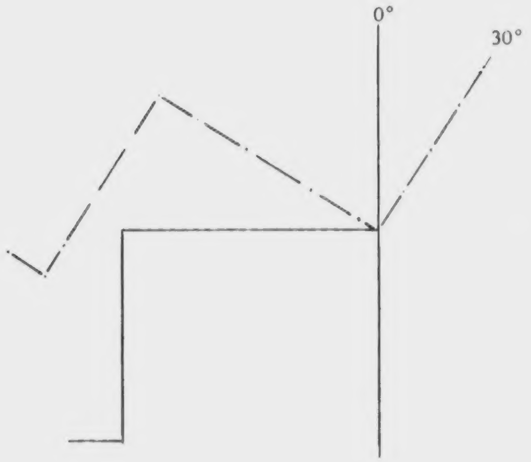

Figure 1 Seating Orientations

	SEATING POSITION					
	BACK EXTENSOR		HIP ADDUCTOR		ANKLE PLANTAR FLEXOR	
	0	30	0	30	0	30
NO	5	5	3	3	5	5
X	2.9	4.8	3.9	8.3	3.5	5.1
SD	3.4	5.6	4.9	10.9	5.0	6.6
SEM	1.4	2.2	2.3	5.1	2.0	2.6

Table 1 Means and standard error of the mean for EMG activity for the 3 muscles a 0 and 30 degree body orientations.

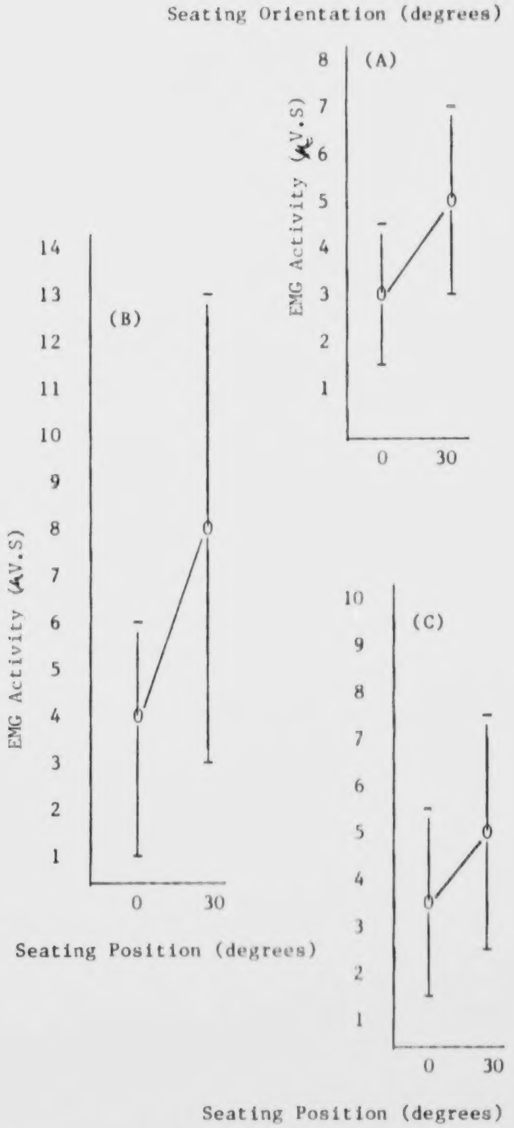

Fig. 2

Mean EMG Activity Plotted against seat orientations (A - Back Extensor, B - Hip Adductor, C - Ankle Plantar Flexor) One standard error of the mean is shown for each orientation.

DYNAMIC MONITORING AND FEEDBACK OF KYPHOTIC SITTING POSTURE FOR CHILDREN WITH CEREBRAL PALSY

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ABSTRACT - A recently developed spinal posture tracking device is being utilized to monitor the kyphotic sitting posture of children with cerebral palsy. Promising preliminary results suggest a technique for assisting in the correction and possible prevention of this posture.

RÉSUMÉ - Un nouvel appareil de poursuite de la position de la colonne vertébrale sert à surveiller la posture assise cyphotique des enfants atteints de paralysie cérébrale. Des résultats préliminaires encourageants font poindre une technique qui permettrait de corriger, voire de prévenir cette posture.

Introduction

This study focuses on the development of a reliable quantification tool to be used in assessing the sitting posture of children with neurological disorders, primarily cerebral palsy.

Postural deviations in patients with neurological disorders are usually subsequent to muscular tone abnormalities, disturbance in the proprioceptive system and the actions of gravitational forces.

The stability and dynamic alignment of the spine is a result of the small "unconscious" movements in each motion segment of the spine which is influenced by the antigravity apparatus, consisting of the sensory and muscle-ligamentous systems.

The interplay of anatomical, physiological and gravitational forces that affect spinal alignment are particularly active in the vertical position, that is in both standing and sitting. For many children with cerebral palsy, sitting is the most frequent postural position. A child exhibiting predominantly a flexion type of spasticity is almost constantly pulled forward by gravity, accentuating flexion and stooped posture. Often muscle imbalance produces a tendency to lean laterally and predispose the child to trunk torsion. In such circumstances, children when left for extended periods of time gradually acquire structural deformations which can become irreversible using traditional physical therapies.

It is a major concern for therapists to decrease the influence of abnormal reflexes by proper positioning, facilitation of coordinated interactions of muscles and promotion of stability particularly in the trunk and pelvis.

Evaluation of sitting posture for these children is important. It is anticipated that our concept of dynamic monitoring of sitting posture will result in an improved effectiveness of treatment planning and, in addition, will help to reduce problems consequent to improper sitting posture.

To date sitting posture assessment techniques have utilized static positions for example, x-ray, Shadow-Moire topography and photography. Some of the existing dynamic posture tracking methods like cinematography or video-digitization are slow, tedious and do not provide instant information about desired parameters. Consequently, these dynamic tracking methods are not used for clinical assessments of lengthy duration.

This new prototype system dynamically evaluates sitting posture, providing results and interpretations immediately. Effects of any variables or interventions such as different cushions or seat-backs or voluntary spinal extension are readily observed.

Methodology

The tracking system[1] consists of a lightweight helmet frame which is fitted snugly but comfortably onto a child's head. Over the apex of the head, the top of this helmet was attached to a horizontal tracking member by a sliding sleeve and rod connection mounted on a swivel head with a wide range of motion. The horizontal tracking arm was free to move in the horizontal plane, and was connected by a four-bar linkage to a vertical tracking transducer.

All mechanical linkages were designed for maximum range of motion with minimal friction and reactive motion forces. Thus the child could maintain head angle in any position without compromising the tracking mechanism.

The processed transducer output provided continuous information about the relative linear displacement between the seat and upper-most head position.

Paraspinal electromyographic (EMG), potentials at the mid-thoracic and lumbar levels were

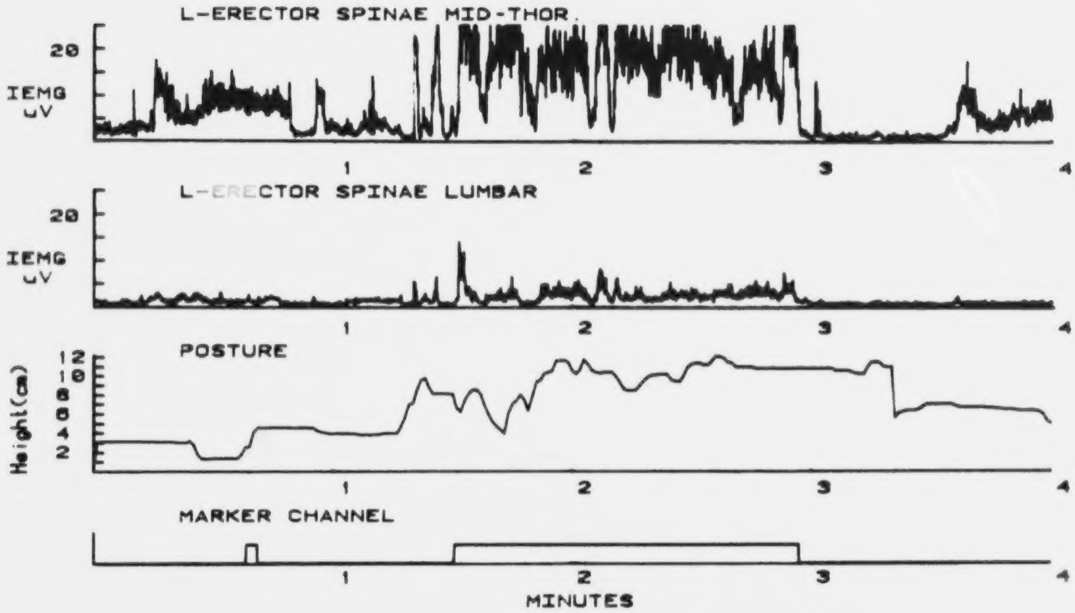

Figure 1: Recorded results of a four minute segment of monitoring paraspinal EMG, back extension length and a marker channel from a 6-year old body with cerebral palsy.

recorded simultaneously to provide information concerning muscle action, fatigue, relative strength and phasing during different sitting positions.

Observations

During preliminary studies, two young children with cerebral palsy (spastic diplegia) aged 6 years, were monitored over a ten minute period for three sessions each. The first four minutes required the children to sit in their normal position while watching a television movie. During the final six minutes, each child was asked, and continuously coaxed into sitting "as straight and as high" as possible. This allowed us to observe the ability to self correct posture while recording the behaviour of the selected muscles through the different ranges of extension.

Figure 1 presents the results for four minutes of recording of spinal extension tracking with simultaneous integrated EMG activity. With the limited recordings, mid-thoracic unilateral erector spinal signals increased substantially when the child was asked to sit up.

Lumbar erector spinal signals also increased but not to the same degree as the mid-thoracic signals. Upon verbal command, the children could extend their backs with an increase in vertical height of approximately 6-8 cm.

Discussion

In pilot studies this device has proven accurate, easy to use, effective and inexpensive to maintain. Future plans call for recording more channels of EMG to study symmetry of muscle action while sitting, evaluation of the effects of seat angle on posture and muscle activity, correlation between hamstring tension and posture, as well as utilizing this device to provide feedback and subsequent motivation modalities as a tool for increasing the awareness of correct posture.

Other persons with neuromuscular, congenital, traumatic or post-operative disorders and consequent posture abnormalities may also benefit from such a device.

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TOWARDS MATCHING NEEDS WITH TECHNICAL APPROACHES IN SPECIALIZED SEATING

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ABSTRACT - A summary presentation of a preliminary effort towards defining seating and posturing needs of a specific population (C.P.); combined with a conceptual framework for matching these needs to the generic types of current seating approaches. The purpose being to develop decision-making guidelines for clinicians working in specialized seating service programs.

RÉSUMÉ - Une présentation sommaire des travaux préliminaires faits pour définir les besoins d'une population précise (P.C.) en matière de posture et de position assise. Présentation d'un cadre de travail conceptuel pour faire correspondre ces besoins avec les différentes approches actuelles en matière de position assise. Le but est d'élaborer des lignes directrices pour permettre aux médecins qui assurent des services spécialisés en matière de position assise de prendre des décisions.

PROBLEM

When considering individuals with "brain damage" there are two principle factors which most significantly effect the needs definition for positioning and seating: the nature and degree of the muscle tone; and the existence, or potential for, skeletal deformity. The interaction between the two above factors is highly complex involving primitive reflex patterns, assymetry of muscle tone, deformity, joint contractures, all of which can change as the child tires, attempts functional activity and matures. It is usually only those clinicians that have specialized training in pediatric neuromotor pathologies that can fully understand and integrate these concepts into clinical seating practices. It is therefore impractical to expect that every clinician and/or private facility involved in specialized seating will gain the depth of training and insight needed to fully integrate these complex concepts as they relate to prescribing and providing specialized seating.

A COMPROMISE APPROACH

The following scheme is being developed as a simplified means of categorizing the nature and degree of neuromotor pathological involvment in a two dimensional array, which addresses the two principle factors indicated above. This can be further thought of as a problem definition matrix which has been arbitrarily defined so that it relates to the existing types of seating approaches being utilized today. The second component of the scheme involves the categorization of the technical seating approaches. The combination of the categorization schemes provides a conceptual framework and clinical guideline to aid in the matching of client needs with specific technical options that may exist now or be available in the future. The scheme also helps to indicate the diversity of needs of individuals in this population and the variety of seating approaches that can be considered for potential solutions and application.

CATEGORIZATION OF NEEDS

The problem definition matrix (Fig. I) contains the two prime factors; skeletal deformity and degree of abnormal tone. Clinical experience has suggested the existence of three identifiable groups of individuals with varying degrees of tone and deformity involvement. Each group can be defined based upon the degree to which their tone and skeletal involvement has effected their head control (HC); trunk control (TC); fine motor skills (FMS); skeletal asymmetry (SA); and joint range of motion (ROM). If we define the degree of abnormal tone in terms of good, fair, and poor and skeletal deformity in terms of mild, moderate, and severe we have the basis for conceptualizing and communicating degrees of involvement related to needs for posturing and body support.

NEUROMOTOR CONTROL

DEFORMITY

NORMAL	GOOD	FAIR	POOR
MILD	GROUP I		
MODERATE	GROUP II		
SEVERE	GROUP III		

Fig. 1 - Problem Definition Matrix

Problem Definition Matrix: with the aid of the above matrix we can describe Groups I, II, and III as follows:

Group I: Good head control, good to fair trunk control, good to fair fine motor skills, symmetrical posturing readily attainable, and joint range of motions (ROM) within normal limits.

Group II: Good to fair head control, fair to poor trunk control, fair to poor fine motor skills, up to and including moderate deformities, within the 90/90/90 posturing position usually attainable.

Group III: Generally fair to poor head control, poor trunk control, poor fine motor skills, deformities at the severe end of the scale, with limitation to ROM due to contractures resulting in difficulty to impossibility of attaining the 90/90/90 seated posture.

NOTE: Definitions of the terms good, fair, poor, mild, moderate, and severe have been developed.

B. Categorization of Technical Approaches

Now that we have a basic method for describing the needs in terms of functional posturing abilities and skeletal deformity, the remaining task is to gain a complimentary perspective regarding possible seating options.

Type I: Non-contoured Support Surfaces: Any approach using non-contoured seating components designed to provide support for the body using essentially flat resilient surfaces. Control of lateral motion of body segments is generally not provided (Ex: Simple Foam and Plywood Inserts).

Type II: Multiadjustable Systems: Any seating approach that is characterized by having a wide range of adjustments to its supporting surfaces through use of adjustable mechanical components. The system may or may not have an integral adjustable wheel base (Ex: Mulholland Growth System (1)).

Type III: Standardized Modules: Seating approaches that are characterized by use of pre-contoured standardized support modules combined with some additional adjustable features (Ex: MPI System (2)).

Type IV: Custom Contoured: Any seating approach that is characterized by the fabrication of contoured support surfaces to meet the customized needs of an individual.

a) Complex Foam and Plywood Approach (F&P): Any system comprised of body contoured support surfaces using traditional foam and plywood technology (Ex: Ontario Crippled Children's Center System (3)).

b) Traditional Orthotic Approach: Any custom contoured system using the procedure of taking a body impression with plaster bandage, followed by producing a positive model, followed by the fabrication of an intimate body support using thermoforming materials.

c) Vacuum Consolidation Approach (VCA): Any system using atmospheric pressure to consolidate a vacuum bag containing small particles for purposes of either transferring a body shape or creating the definitive body support component(s) directly.

   1.) 2-step VCA: Any approach which uses the VCA to transfer a body shape in order to produce a positive mold of the body over which the definitive seat is produced (Ex: Gillette Body Support System (4)).

   2.) 1-step VCA: Any VCA process used to create a definitive contoured seat directly without producing a positive model of the body as an interim step (Ex: DESMO System (5), The Bead Seat System (6)).

d) Foaming Approach: Any approach involving the fabrication of custom contoured support surfaces using foaming polymers (example: polyurethane foams).

   1.) 2-step Foaming Process: Any foaming approach that depends on the creation of a positive model against which the final foam surfaces are produced (Ex: Foam-In-Box Technique)

   2.) 1-step Foaming Process: Any foaming approach using rigid or flexible foams in which the final contoured components are produced in one step using the person as the model around which the components are directly contoured (Ex: Foam-In- Place (7), University of Tennessee (flexible foam)).

e) Shapeable Matricies: Any approach that uses a system of interlocking prefabricated modules designed to permit direct contouring followed by locking or fixing of the shape for use as the definitive seat (example: Shapeable Matrix System - Bradu-London, England (8); Shapeable Matrix System - Meru-University of British Columbia, Canada (9)).

Type V: Hybrid Systems: Any seating approach that utilizes two or more of the above techniques (Ex: Spinal Support System - Hospital for Sick Children, Toronto, Canada).

NEEDS (C.P.)		GENERIC SEATING OPTIONS							
					TYPE IV - CONTOURED				
GROUPS	SUPPORT/ POSTURING REQUIREMENTS	TYPE I NON CONTOURED	TYPE II MULTI ADJUSTABLE	TYPE III PRE-CONTOURED MODULES	F & P	ORTHOTIC	VCA 1-Step	FOAMING	MATRICIES
Group I		(*) (+)							
Pelvis	firm flat base								
Trunk	firm flat support								
Head	none								
Feet	90° support								
Group II			(**) (++)	(*) (++)	(*) (++)	(*) (++)			(**) (++)
Pelvis	midline orientation								
Trunk	midline orientation								
Head	removable support								
Feet	90° support								
Group III					(**) (+++) (++)		(**) (+++) (++)	(**) (***) (+++) (++)	(**) (+++) (++)
Pelvis	accommodate deformity								
Trunk	accommodate deformity								
Head	full support								
Feet	accommodate deformity								

Deformity: (*) mild to moderate (**) moderate to severe (***) severe
Control: (+) good to fair (++) fair to poor (+++) poor

Fig. II - Needs vs Options

SUMMARY DISCUSSION

This paper has presented a conceptual framework for formulating seating needs for the cerebral palsy population combined with a brief description of the currently used generic approaches. Fig. II indicates the range of generic options that are available to solve specific individual needs within and across the defined groups. Choice of specific seating systems will be dictated by local availability, cost, and compatibility with the holistic needs, daily activities, and life goals of an individual and their care givers.

It is possible to speculate how this approach could be expanded to include the needs of other populations, for example; persons with muscular dystrophy, spinal cord injury, arthritis, osteogenesis imperfecta, and others requiring specialized seating and posturing support.

Furthermore, the addition of a third dimension to the matrix could bring in the environmental and usage factors that also directly impact upon clinical decision-making.

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TOWARDS AN ECONOMICAL POSTURAL SEATING SYSTEM USING AN ADJUSTABLE MESH

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ABSTRACT - A specialized seating system is under development which utilizes a network of individually controlled nylon straps to form an adjustable support surface. Potential advantages of this approach include lower overall costs, enhanced versatility and simplicity of construction.

RÉSUMÉ - Un nouveau système de siège spécial consiste en courroies de nylon individuellement réglables qui forment une surface de support variable. Ce système serait moins coûteux, plus souple et plus simple à construire.

Introduction

The importance of proper seating for the disabled is widely recognized. Benefits include such factors as increased comfort, enhanced functional abilities and the prevention of decubitus ulcers. A common objective in seating is the provision of postural support while accommodating abnormal muscle tone or physical deformities. Typical of this type of application are seating systems for those with cerebral palsy.

In severe cases, seating systems for the cerebral palsy population must accommodate a wide range of muscle and/or orthopedic related problems. These needs have been addressed by a number of different approaches including conventional upholstery methods, custom-molding using polyurethane foams or a bead/resin mixture, and the assembly of small plastic modules to form the appropriately shaped contours. Although effective, these techniques suffer from a number of drawbacks. For example, some systems require considerable technical skills or expensive equipment to produce. Others jeopardize patient comfort by providing a hard seating surface or minimal air circulation around the body. Furthermore, many existing methods do not facilitate subsequent growth adjustments for children.

In response to these limitations, a new approach has been proposed. The basic principle of this design involves a flexible open weave mesh which can be adjusted to provide suitable postural support. This type of arrangement would allow a wide range of patients to be accommodated with a minimum of customized construction.

Background of Concept

The use of a mesh for seating is not new. The United States Air Force experimented with this idea over thirty years ago (Hertzberg and Colgan, 1948). Their objective at that time was to develop a suitable aircraft seat for long range flights. The desired body posture was maintained by shaping the external frame as well as adjusting the tension of the nylon netting. The resulting units were lightweight and were found to be more comfortable than conventional airplane seats in tests lasting 8 - 12 hours. More recently, a Calgary-based company has introduced a similar type of seat for use by the disabled (Adaptive Engineering, 1982). The netting is adjusted to accommodate the individual and then covered with a thin cushioning material such as sheepskin.

The proposed design extends the capabilities of this concept by incorporating a two dimensional array of individual supporting members. These supporting members which may be strings or straps, are arranged such that they intersect perpendicularly across the seating surface. In this way, they are free to move relative to each other. This contrasts with the standard netting in which the support strings are fixed at each intersection.

This subtle difference can produce significant changes in the control capabilities of the support surface. For example, by selectively increasing the lengths of appropriate supporting members, the configuration of the mesh can be changed to more closely resemble that of the applied load. The concept also suggests the control of pressure distribution. Theoretically, it is possible to alter the pressure at any of the intersecting points by adjusting the two supporting members which form the coordinates of that point. This would result in the enhanced ability to support complex shapes while effectively accommodating pressure-sensitive areas. The operation of this concept was first investigated using an experimental model consisting of nylon strings which intersected at right angles to form a close mesh (Ginpil et al. 1982). A series of experiments were conducted with different load shapes and weights which demonstrated the shape accommodation and pressure control capabilities of this approach.

Practical Application

The concept was then modified for practical application. An external tubular steel frame was constructed which supported a network of 5 cm. wide nylon straps. Straps were substituted for the strings used in the earlier model in order to reduce the number of adjustments to a managable level. Preliminary clinical trials were conducted with two children having cerebral palsy. The results of these tests supported the hypothesis that even severely involved patients could be accommodated in this way.

Present developmental work has strived to maintain the desirable properties of this approach while addressing the operational problems indicated in earlier models. The current design shown in Figure 1 permits a wide range of seating dimensions by utilizing a telescoping arrangement for the tubular steel frame. A locking hinge is also used to adjust the angle of the back support. Nylon straps, approximately 4 cm. in width, are used to create the adjustable mesh. This high strength material is durable and resists stretching. It also possesses very low frictional characteristics, allowing the straps to slide over each other easily during adjustments. Greater control during fittings has been facilitated by dividing the longitudinal straps into two sections, allowing separate adjustments for the back and seat/leg areas. The straps are interwoven through a standard fixed netting of approximately 4.5 cm. mesh size. This serves the dual purpose of holding the straps in their relative positions while providing a continuity of support throughout the seating surface. The support surface itself is attached to the external frame by means of a fabric sleeve. This vinyl-coated nylon material drapes around the metal tubing and fastens to itself with releasable snaps. The straps and netting are permanently sewn to the sleeve on one side of the frame while remaining free for adjustment on the opposite side. A proposed fitting procedure would use a temporary clamping device to facilitate changes in strap lengths on the free side. The position of the individual straps would then be marked and sewn with the netting to the sleeve. Once sewn on all sides, the total mesh support could be removed for cleaning by unfastening the complete sleeve from the frame. A slip- on-cover has also been provided, primarily to enhance the cosmesis of the seat. Currently a two-way stretch terry-cloth is used which is sufficiently elastic to adapt to the individual seating configuration (See Figure 2).

This type of approach to specialized seating appears to offer several desirable features. First, it enables a wide range of shape accommodation as well as the control of pressure distribution through the adjustment of individual strap lengths. The seat should also be economical to produce due to the simplified construction technique. Cost savings would therefore apply to both the initial fitting and subsequent growth modifications. In addition, the assembly process would not require expensive equipment or highly trained personnel. Comfort would be enhanced by the forgiving nature of the support surface coupled with the provision of ample air circulation to minimize excessive heat and moisture in the seating area.

Future Work

Future work will address the increased versatility of the design in addition to clinical testing. Further investigation will be made of the optimal mesh arrangement including the proper width, number and spacing of support straps. Fitting procedures will be examined to increase the accuracy and ease of adjustments. A modular approach will be considered for the frame construction, allowing precut components to be assembled to the appropriate seating dimensions and angles. Provision will also be made for the addition of lateral supports and restraining straps. Finally, various seat cover materials will be tried to take greater advantage of the air circulation properties of this approach. Upon completion of this developmental phase, a clinical evaluation is planned to compare the performance of this seating system to that of the custom upholstery method presently used at the Ontario Crippled Children's Centre. The study would consider the effectiveness of the seats in providing postural support to severely involved children with cerebral palsy. This information will then be assessed in light of the cost factors associated with the two systems.

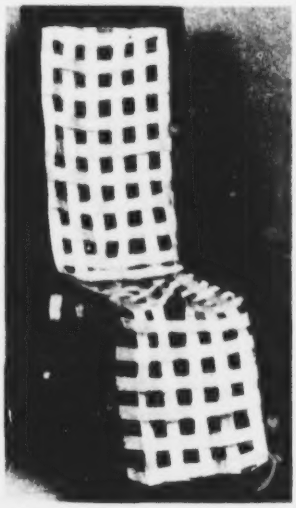

Figure 1: Prototype of proposed seating system showing adjustable strap and netting arrangement

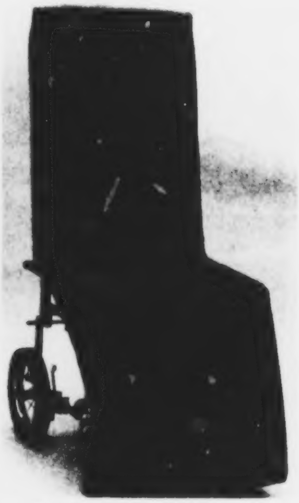

Figure 2: Seating prototype shown with stretch terry-cloth cover

Acknowledgements

1. Health and Welfare Canada, for support of M.A.Sc. research of seating concept.
2. Conn Smythe Research Foundation For Crippled Children for support of prototype development.

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SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 22

BIOMECHANICS/
BIOMÉCANIQUES

MOTOR UNIT ACTION-POTENTIAL GENERATION: ELECTRODIAGNOSTIC MODEL DEVELOPMENT BY LINEAR PREDICTION

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ABSTRACT - The paper presents the development of inverse analysis of EMG, in terms of Linear Predictive Coding (LPC) model and its parametric simulation of recorded single motor unit action potential for electrodiagnosis of such neuromuscular disorders as motor neuron degeneration, regeneration after lesion and myopathy.

I. BACKGROUND & RATIONALE

In neuromuscular rehabilitation engineering, the electrodiagnostic methodology has entailed pattern recognition of the monitored EMG signal and its correlation to neuromuscular disorders. Figure 1 shows a mechanistic model of generation of motor unit action potential, made up of the individual motor unit, in accordance with their spatial and temporal distribution.

However, the single motor unit action potential (SMUAP) waveform patterns are difficult to recognize for differential diagnosis in such cases as degenerative diseases of motor neurons, regeneration after nerve lesion, and in myopathy. To this end, we have applied Linear Predictive Coding (LPC) method to model a given MUAP in order to better characterize MUAPs in nerve and muscle lesions.

II. METHODOLOGY & RESULTS

1. Data Acquisition:

Myoelectric signals were simultaneously recorded from the surface and from 5 cm depth of the tibialis anterior of a healthy subject; monopolar needles were used to record the motor unit action potentials. The subject was trained to produce single motor unit firing. Figure 2 shows the data acquisition system.

The recorded SMUAP signal was digitized, using a 2 channel 8-bit A/D converter controlled by Intel SDK85 microprocessor system. This front-end microcomputer system has been built primarily to digitise two signals simultaneously and store the digitized data in its buffer memory of 16 K. A 10 KHz sampling rate has been used to digitize the SMUAP signals.

The digitized data from the 16 K buffer memory is uploaded to CYBER 170/815 main frame computer for storage and further processing. The buffer amplifiers preceding the A/D convertors are bandlimited to 5 KHz thus effecting antialiasing.

The data files on the CYBER disk are preprocessed to remove any dc bias. The MUAP's which appear as spikes on the data file are extracted by applying a hamming window positioned so as to include a MUAP. A typical MUAP extracted from the data file is shown in fig. 3.

2. Power Spectrum of the Extracted SMUAP

The spectrum of extracted SMUAP is obtained, using conventional fast Fourier transform (FFT) programs on the CYBER. The average spectrum of several spikes is indicated in fig.

3. Modelling SMUAP by Linear Predictive Coding (LPC)

The SMUAP signal power spectrum P(w), obtained by FFT analysis, is matched by an all-pole LPC model spectrum $\tilde{P}(\omega)$, [1],, such that the total error energy between the SMUAP signal and model signal is minimized. Let the all-pole model transfer function be represented by $\tilde{s}(e^{j\omega})$:

$$\tilde{s}(e^{j\omega}) = \frac{G}{1 + \sum_{i=1}^{p} a_i e^{-j\omega i}} \tag{1}$$

wherein (i) p is the no. of poles (predictor order) in the transfer function, (ii) a_i(s) are the predictor coefficients, and (iii) G is a gain constant.

The model spectrum $\tilde{P}(\omega)$, to match the FFT derived spectrum $P(\omega)$, is given by:

$$\tilde{P}(\omega) = |\tilde{s}(e^{jw})|^2 = \frac{G^2}{\left| 1 + \sum_{i=1}^{p} a_i e^{-j\omega i} \right|^2} \tag{2}$$

Now, for an arbitrary number of poles "p", the a_i's are determined so as to minimise the total energy (E) of the error signal

$$E = \frac{1}{2\pi} \int_{-\pi}^{\pi} P(\omega) \left| 1 + \sum_{i=1}^{p} a_i e^{-j\omega i} \right|^2 d\omega \text{ , i.e.,} \tag{3}$$

$$\frac{\partial E}{\partial a_k} = 2 \left| R_k + \sum_{i=1}^{p} a_i R_{|k-i|} \right| = 0; \tag{4}$$

or,

$$\text{i.e.,} \quad \sum_{i=1}^{p} a_i R_{|k-i|} = -R_k; \; 1 \le K \le p \tag{5}$$

where R_i is the auto correlation function of the given signal obtained here from the power spectrum. The solution of equation (5) would yield the predictor coefficients a_i's. The gain factor G^2 can be determined by conserving energy between $P(\omega)$ and $\tilde{P}(\omega)$. It can be shown that:

$$G^2 = Ro + \sum_{i=1}^{p} a_i R_i , \tag{6}$$

and this is the minimum error.

If the predictor order "p" is sufficiently large, then $\tilde{P}(\omega)$ approximates to $P(\omega)$ as $p \to \infty$. Therefore, from equation (1), an all-pole generating model of the signal could be defined in Z domain (assuming gain to be unity), i.e.

$$\tilde{s}(z) = \frac{1}{\left| 1 + \sum_{i=1}^{p} a_i z^{-i} \right|} ; \tag{7}$$

4. LPC Model Simulation

The LP analysis is carried out on the MUAP data file. The LP model, corresponding to fig. 1, is shown in fig. 5. The autocorrelation coefficients necessary to calculate the predictor constants can directly be obtained from the signal itself. Once the predictor coefficients are evaluated, the zeros are appended to the sequence containing $a_1, a_2, \ldots, a_p$, so that an arbitrary frequency resolution can be obtained when FFT is performed on this sequence. The model power spectrum is then obtained by simply inverting the squared magnitude of the FFT of the above sequence. Figure 6 shows the LP model power spectrum of the SMUAP for a predictor order of 6. The model parameter values are indicated in the figure caption.

We have thereby demonstrated the development of LPC electrodiagnostic model for motor unit action potential generation. The evaluated LP model parameters can be correlated to the physiological model (figure 1) of motor unit action potentials.

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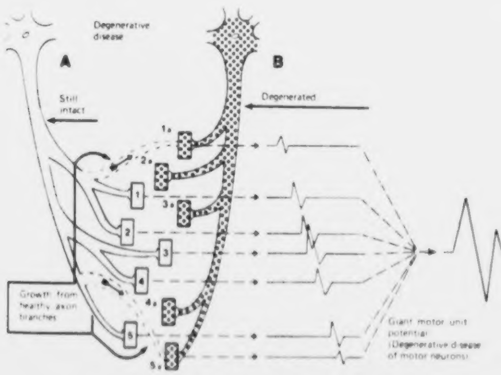

Degenerative disease
A
B
Still intact
Degenerated
1
2
3
4
5
Growth from healthy axon branches
Giant motor unit potential (Degenerative disease of motor neurons)

Figure 1: Mechanistic Model

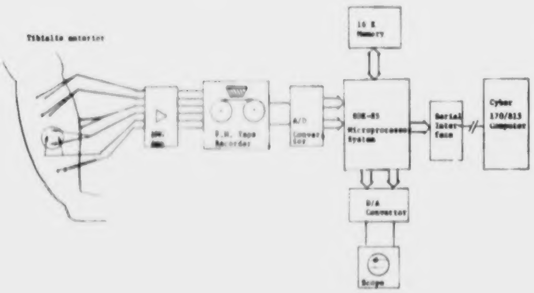

Tibialis anterior
F.M. Tape Recorder
A/D Converter
16 K Memory
SDK-85 Microprocessor System
Serial Interface
Cyber 170/815 Computer
D/A Convertor
Scope

Figure 2: Data Acquisition System

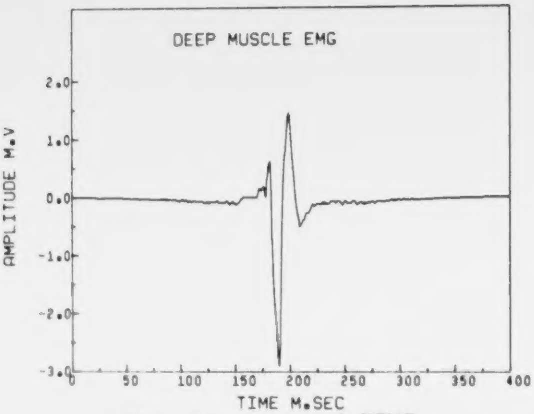


Figure 3: Extracted SMUAP

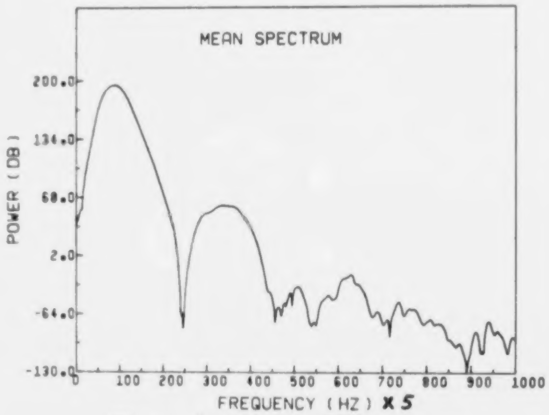


Figure 4: Average FFT Spectrum

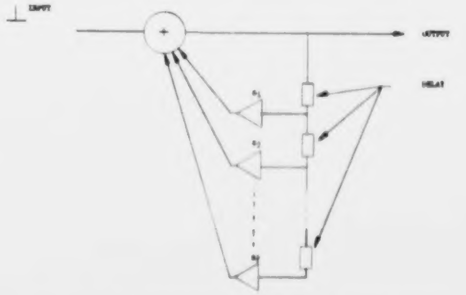
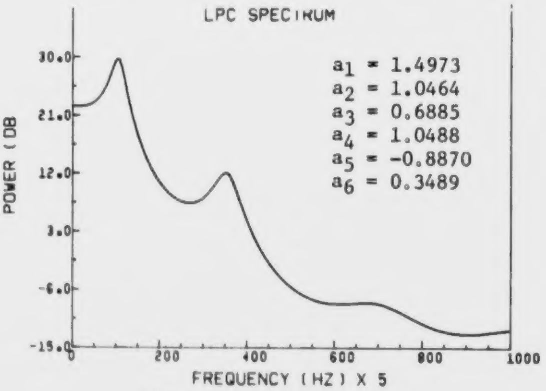

INPUT
+
OUTPUT
DELAY

Figure 5: Generating Model Structure



$a_1 = 1.4973$
$a_2 = 1.0464$
$a_3 = 0.6885$
$a_4 = 1.0488$
$a_5 = -0.8870$
$a_6 = 0.3489$

Figure 6: LPC Spectrum

PATH OF MOTION STUDIES OF THE GLENO-HUMERAL JOINT

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ABSTRACT - A mechanical and an electro-mechanical goniometer are described which provide a 2- and 3-dimensional representation of the path of motion of the gleno-humeral joint. Both systems have been designed as clinical tools to provide objective measures of the functional range of motion of the shoulder.

RÉSUMÉ - On décrit un goniomètre mécanique et un goniomètre électro-mécanique de l'épaule qui fournissent une représentation en 2 et 3 dimensions du mouvement de l'articulation gléno-humérale. Ces deux systèmes ont été conçus comme des outils cliniques permettant d'obtenir des mesures objectives de l'étendue des mouvements fonctionnels de l'épaule.

INTRODUCTION

The objective of this research is to determine those objective measures of motion at the gleno-humeral joint which can be used for: 1) serial evaluation of shoulder function, 2) evaluation of upper extremity function and 3) diagnosis of shoulder pathology. Although sophisticated measurement systems have been applied to shoulder studies the manual goniometer remains the principle clinical tool (1,2). Early studies were based upon physical examinations with a goniometric measurements of range of motion in selected planes (3) and estimations of skeletal motion from sequential x-rays (4,5). More recently shoulder function has been studied using a variety of measurement systems for motion, force and muscle activity (6,7). However, the latter measurement systems require instrumentation unavailable to most orthopaedic or therapy departments. Therefore the principle measurement tool is still the manual goniometer used to determine passive and active ranges of motion.

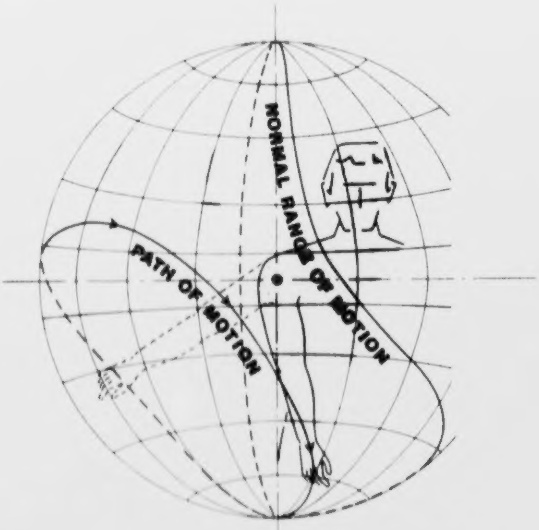
This research seeks to evaluate the present clinical approach and to develop simple and affordable alternatives if required.

METHOD

The Shoulder Model

The shoulder has the most complicated joint motion in the body as the girdle is comprised of five separate articular joints. In the preliminary phase of this research the simplest measurement problem was considered first, sequential evaluation of the gleno-humeral joint during rehabilitation. The principle simplifying assumption was that the shoulder could be represented as a ball and socket joint attached rigidly to the trunk. Normal motion within the shoulder girdle was expected to introduce an uncertainty with respect to the location of the rotational centre of humeral head of approximately in a radius of 3 cm.

A model of the resultant path of motion subtended by the head of the humerus would describe a locus on the surface of a sphere approximately centred at the gleno-humeral joint. (See Figure 1). In addition the humerus has some degree of axial rotation available for each point on this locus, representing the internal and external rotation as limited by soft and hard tissues within the shoulder girdle. Initially internal and external rotation will be determined separately for preselected positions based on present clinical practice. During the next phase of instrumentation this measure will be integrated directly into the system.



SHOULDER MOTION ENVELOPE

Figure 1.

The Mechanical Scribe:

Initially a mechanical scribe was developed to monitor the path of motion (POM) of the gleno-humeral joint through a mechanical linkage. A telescoping arm pivots through a ball and socket joint and is tipped with a telescoping pen. When the linkage arm is moved through space a projection of this motion is recorded on a paper target. Calibration for such a simple mechanism is only possible if the body motions of the operator are constrained, minimum linkage lengths defined and subject alignment standardized.

A trigonometrically calibrated polar angle-angle scale was provided for reference on each target sheet. This type of projection, however, produces peripheral distortions and recordings must be taken from separate subject orientations to record the full POM.

The Electro-Mechanical Scribe:

A second scribe was developed to provide direct three dimensional representation of the POM. The mechanical linkages were replaced by a gimbal supporting a sleeve for a sliding lightweight tube. The gimbal was instrumented with two potentiometers to detect angular displacement and a third on a running wheel to measure change in length. The three channels of data describe the position of the end of the sliding tube in space, see Figure 2.

The data is collected and analysed on an Apple II microcomputer and displayed on its colour monitor. This instrument tracks the motion of a point in space and hence can be used either for measuring either shoulder or hand motion.

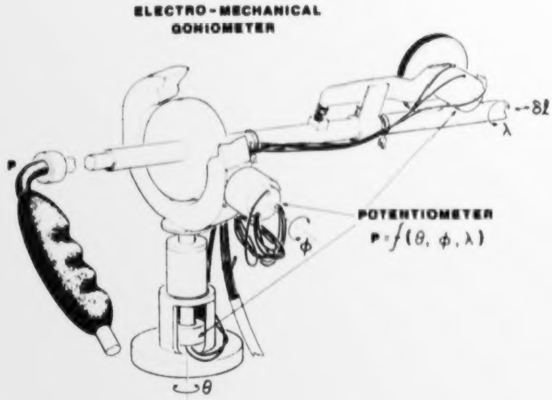


Figure 2

Preliminary Analysis:

During the exploratory phase of data collection displays have been developed to enhance qualitative pattern recognition by the health care team members. For the mechanical scribe a standard examination regimen was used for intra- and intersubject comparisons. A range of preliminary qualitative results will be presented to demonstrate the capabilities of this mechanical recorder.

It is addition the following quantitative studies reported on:

1. Calibration: a calculation of the resolution of the scribe experimental verification from bench tests;
2. Normal Subject Studies: baseline path of motion data will be collected and the resultant patterns presented;
3. Data Analysis: the normal path of motion data will be characterized by selected parameters and intra- and intersubject variabilities determined; and
4. Patient Data: preliminary patient data will be compared by clinically classified pathological conditions.

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EVALUATION OF INFERIOR SUBLUXATION OF THE SHOULDER USING A STANDARD X-RAY TECHNIQUE AND SPATIAL RESECTION

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ABSTRACT - A method of evaluation of inferior subluxation of the shoulder using a bi-planar standardized x-ray technique and a photogrammetric algorithm is presented. The three-dimensional indices of shoulder subluxation thus obtained and the resection technique are tested in two validation experiments.

RÉSUMÉ - Une technique d'évaluation de la subluxation inférieure de l'épaule utilisant une méthode radiologique biplanaire et un algorithme photogrammétrique est présentée. Les indices tridimensionnels ainsi obtenus et la précision de la technique sont évalués au cours de deux tests de validation.

Effective treatment of the inferior subluxation the shoulder relies in part on its early diagnosis as well as on an accurate evaluation. In subluxation of the shoulder, the relative movement between the scapula and the humerus is not limited to one plane but is effectively occuring in three-dimensional space. This paper presents a method of evaluating shoulder subluxation using a spatial resection technique and standardized x-rays.

Recently one has seen a proliferation of standardized x-ray techniques used to quantitavely describe bony structures as varied as the spine(1), the knee (2) and the foot(3). The advantage of standardized x-rays over conventional x-rays lies in the fact that they can be corrected for image distortion and magnification and thereafter used as input to three-dimensional models of imaged bony structures. Various levels of accuracy have been reported, for example Brown (1) estimates an accuracy of ± 1.0 mm on the position of points on the vertebra whereas Lippert (2) obtains ± 0.1 mm accuracy for small steel balls incrusted in a bone. In the first case, description of spinal curvature is sought while in the second case, the relative displacement between the femur and an implant is measured. In view of their respective applications, both methods are said to be satisfactory. An estimate of the order of accuracy needed for an early diagnosis of shoulder subluxation is of ± 5 mm on the position of chosen anatomical landmarks. This represents a significant improvement over palpation and present x-ray evaluations.

The technique developed to evaluate shoulder subluxation requires three distinct steps: a) the production of two differently oriented standardized x-ray images, b) data acquisition, the identification of calibration objects and anatomical landmark images in both x-rays and their expresion in a digital form, c) data reduction by analytic algorithm resulting in the determination of three-dimensional positions of digitized anatomical landmarks.

A) X-ray production: From the many possible x-ray views of the shoulder, the anterior-posterior and 45 degree oblique views are chosen. Their common use in present clinical practice and the fact that anatomical landmarks of interest are imaged in both x-rays delimit this choice. Production of repeatable standardized x-rays essentially requires that the position of the shoulder with respect to the x-ray source and film cassette be controlled and that calibration objects be imaged. A special pivoting chair was designed to produce such x-rays. Its use is straightforward, the patient is seated and retained in position by hip and chest belts, the shoulder then centered over the film is ready to be x-rayed in the anterior-posterior view. The oblique view is obtained simply by pivoting the patient by 45 degrees. For both x-rays the source is positioned approximately 1.85 m from the film cassette and 1.6 m from the shoulder.

B) Data acquisition: Coordinates of image points are obtained by placing x-rays on a transluscent digitizing table and pointing images to be transferred directly to the computer mass storage system. First the images of calibration objects are collected, on average sixteen are used, then specific anatomical images are collected. Anatomical landmarks imaged on both x-rays are limited in number, points chosen on the humerus are the most superior aspect of the articular margin and the center of the head, and on the scapula they are the extremities of the coracoid process and of the acromion and the inferior margin of the glenoid cavity. These anatomical landmarks are illustrated in figure 1.

C) Data reduction: The last step in the process of obtaining the three-dimensional position of specified anatomical landmarks is the reduction of image coordinates by an analytic algorithm. The Direct Linear Transformation proposed by Abdel-Aziz (4) is adopted. With sufficient calibration objects imaged, this algorithm directly calculates the space coordinates of non-calibration objects. A minimum of six calibration objects is required for spatial resection, however sixteen are used in order to increase the precision and convergence of the algorithm. Presently these operations are carried out on the University of Montreal's Cyber 855 central computer.

Indices for evaluating inferior subluxation of the shoulder

The spatial position of specified anatomical landmarks do not directly indicate shoulder subluxation. It is rather the relative distance between the humerus and the scapula that is sought. The two indices now calculated consist of the distances between the two points on the humerus and the center of the triangle formed by the three points on the scapula. These indices are illustrated in figure 1. In order to evaluate the accuracy of subluxation indices two experiments were performed.

The first experiment consisted of determining by radiographic technique the distances between small steel balls (1 mm dia.) incrusted in a plexiglass plate, and comparing with distances measured directly by vernier caliper. Repeated measurement of these distances establish their accuracy at ±0.1 mm.

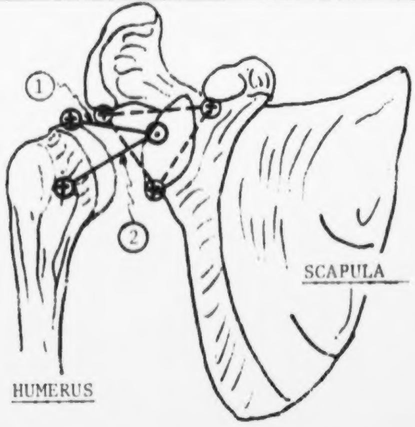

Figure 1 : Anatomical landmarks digitized in x-rays and subluxation indices.

table 1 : DISTANCES BETWEEN OBJECTS

objects	measured distance (mm)	calculated distance (mm)	absolute difference (mm)
1-2	87.2	86.1	1.1
1-3	134.1	135.0	0.9
1-4	264.7	266.1	1.4
2-3	44.2	42.6	1.6
2-4	68.1	70.5	1.4
mean of absolute differences			1.3 mm

Results presented in table 1 indicate that, for objects whose images are small and well defined, the accuracy of the calculated distances between two such points is better than ±1.3 mm. This order of accuracy permits the use of the x-ray technique and resection algorithm for the purpose of evaluating shoulder subluxation.

The second experiment consisted of simulating inferior subluxation of the shoulder. Using a shoulder skeleton with fixed scapula and humerus mounted on a micro-meter platform, it was posible to precisely control the displacement of the latter. Evaluation of this displacement by the proposed technique estimates the accuracy of subluxation measurements and gives an indication of the effect of errors inherent to identification of anatomical images.

table 2 : EVALUATION OF DISPLACEMENT OF THE HUMERUS

index	imposed (mm)	calculated (mm)	absolute difference (mm)
superior point hum.	14.4	19.5	5.1
center of hum. head	14.4	11.6	2.8
mean of absolute differences			3.95 mm

The results presented in table 2 indicate that the dispalcement of the humerus can be determined to an accuracy of 4 mm. Such accuracy is approximately three times less then that obtained with small steel balls, and aptly reflects that identification of the same anatomical landmarks in two differently oriented x-rays is the factor limiting precise spatial resection. Some researchers (2) now implant radio-opaque objects in the bones they x-ray in order to obtain very precise resections. While leaving room for improvement, an accuracy of ±4.0 mm does satisfy our present clinical requirements.

Though this bi-planar x-ray technique is now being used to evaluate inferior subluxation of the shoulder at the Institut de Réadaptation de Montréal, the versatility of the technique permits its application to most investigations requiring a description of the shoulder complex.

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BIOMECHANICAL GUIDELINES FOR SPINAL FRACTURE FIXATION

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ABSTRACT - Based on the analyses of the values of forces induced in the fractured spinal and internal-fixation system structures, the paper provides, for the first time, biomechanical considerations for the employment of appropriate internal fixation systems for distraction-dislocation, wedge and burst vertebral fractures, and fracture-dislocation types of injuries.

RÉSUMÉ - En se basant sur les analyses des grandeurs des forces en jeu dans le système spinal fracturé et dans le dispositif interne d'ostéosynthèse, les auteurs du présent rapport étudient, pour la première fois, les aspects biomécaniques de l'emploi de dispositifs internes d'ostéosynthèse appropriés pour le traitement des luxations, des tassements cunéiformes, des fractures comminutives et des fractures-dislocations.

BACKGROUND AND THEME

The principles of spinal fracture fixation are (1) reconstitution of the supportive spinal stiffness, (2) prevention of further stress on the injured component spinal (vertebral body or ligament) structure, (3) elevation of stress on the spinal cord from the anterior side, (4) rigid fixation of the fractured spinal segment so as to ensure maintenance of the above three objectives.

The four types of spinal injuries, for which we will discuss the appropriate instrumentations, are (i) Distraction-dislocation injury, due to rupture of the ligamentous structures, (ii) Wedge-type fracture of the vertebral body and burst fracture of the vertebral body, involving complete crushing or collapse of the vertebral body, and (iii) Fracture-dislocation injury, due to a combination of crushed vertebral vertebral body and rupture of the ligamentous structures.

The alternative internal-fixation systems under consideration are (i) bilateral compression or distraction rods anchored to the laminae, (ii) Luque-type stiffness-providing rods held in place on the posterior aspect of the lamina by means of wires passed around the rod and each lamina or anchored to the spinous process, (iii) combined distraction and stiffness-restoring rods and (iv) anterior-fixation devices with concommitant wire tension band around the spinous processes. The selection and design of the appropriate internal-fixation system depends on the nature and severity of the injury.

Spinal fracture-fixation system failure and/or its inability to achieve the above objectives is often due to injudicious selection of instrumentation. The purpose of this paper is to (i) delineate the biomechanical basis of selection of appropriate instrumentation, depending on the nature of spinal injury, and (ii) demonstrate the efficacy of the instrumentation, based on the analysis of stress in the injured spinal structures as well as the instrumentation.

INTERNAL-FIXATION OF SPINAL INJURIES

The Distraction-dislocation Injury Fixation

The internal-fixation device takes over the tension-resisting role of the posterior ligamentous structures and maintains stability in flexion bending. Either compression rods or curvature-restoring Luque-type rods (with wire anchored to the spinous process) can be employed (figure 1). In both cases, the tensile force due to flexion-bending is sustained by the rods. The flexion moment for an L-1 level of injury varies from 4 N-m in the case of a subject holding the back straight to 40 N-m in the case of a subject in 90° forward bending.

In the case of compression rod fixation, this bending moment (M) of 40 N-m induces tensile stress of 12 MPa $[(MY/I_{eq})(E_r/E_s)]$ in the rods and a compression force of 330 N to the lamina. In the case of Luque-type stiffness-restoring rods, this bending moment induces compressive bearing forces of 200 N $\{[40N\text{-}m/L(= 1/3\ m)](8 \times 5)\}$ on the posterior aspects of (say, five) adjacent lamina. The use of stiffness-providing rods gives a higher factor-of-safety.

Fixations of Wedge and Burst Fractures of the Vertebral Body

Under flexion bending, the wedge-type fracture results in the lamina above and below the fracture being displaced away from one another; on the other hand, in the case of a burst vertebral body, the lamina above and below the fractured vertebral body move closer to one another (1). Hence to resist these relative displacements of the lamina, compression rods are needed for stable fixation of wedge compression fractures (figure 2), while distraction rods are needed for stable fixation of burst fracture (figure 3). The failure on the part of orthopaedic surgeons to recognize this biomechanical factor results in many cases of failures of internal fixation system (figure 4). However, even if this biomechanical separation of the treatment modalities of these two types of injuries was recognized, such a clinical separation would not be possible.

Hence in the case of a vertebral body fracture, wherein the crushed body may herniate into the cord, it is safer to fix the fracture by means of bilateral contoured Distraction-Segmentally attached rods (i) with their hooks bearing against the lamina in a distraction mode (i.e., under the top lamina and over the bottom one, while subjecting the spine to very slight distraction), and (ii) held in place along their length against the posterior surfaces of the lamina by wires looped around the rod and anchored to the spinous process (figures 5). With the employment of such a hybrid internal-fixation system, even if the hooks did slip off the lamina, the segmental lateral forces (applied to the spine by the wires) would maintain the spinal stiffness, prevent vertebral body collapse (under body weight induced flexion moment) and associated increased compression of the herniated cord.

In this system, the normal forces applied to the spine by the wires provide resistance to flexion bending and collapse of the vertebral column. Thus, the biomechanical analysis, of equilibrium between the torso-weight induced flexion moment on the spine and the extension moment induced by the forces exerted by the wires, yields the order of magnitude of the tensile forces exerted on the anterior surface of the lamina and of the bearing forces exerted on the posterior surface of the lamina to be 500 N each (figure 6).

The Fracture-dislocation Injury Fixation

Herein, both the compression-bearing vertebral body and the tension-bearing posterior ligaments are damaged, and unable to carry out their functional tasks. Also, this results in considerable anterior impingement on the spinal cord.

The conventional technique of using a distraction rod is irrational, due to the absence of intact posterior ligaments to distract against, and due to the non relief of pressure on the spinal cord from the anterior side.

The Luque-type rods are also not adequate for the same reasons.

It is hence recommended that the crushed body be removed, an anterior compression-bearing plug (with an adjustable anatomical height) be placed to bear the compression force during flexion bending, and to resist tension during flexion bending it is recommended that a wire tension bend be placed aroud the adjacent spinous processes to resist tension during flexion bending. With such an internal fixation, it has been shown (2) that the potential for neurological recovery may be achieved, the spinal column stabilised, and early assisted ambulation facilitated.

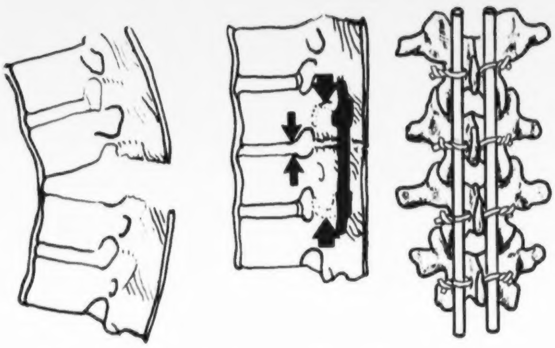


Fig. 1: Compression & Luque fixations for dislocation injury

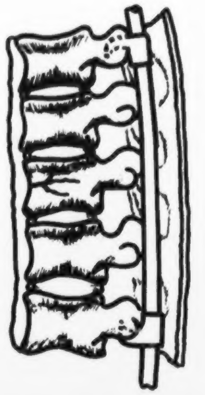


Fig. 2: Compression rods for wedge vertebral fractures

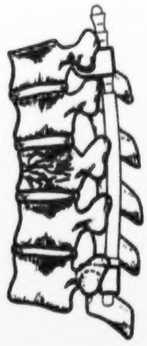
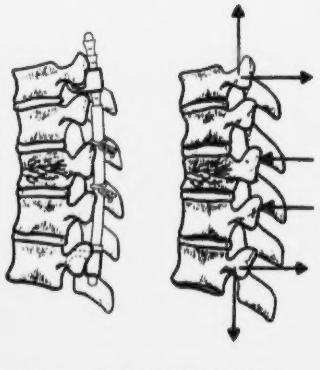


Fig. 3: Distraction rods for burst vertebral fractures

Fig. 4: Clinical failure of distraction rods duets wrong use of fixation device



Figs. 5 & 6: Distraction -Segmentally attached rods and corrective forces for vertebral fracture

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THE RELIABILITY AND VALIDITY OF KNEE JOINT ANGLE MEASUREMENT BY ELECTROGONIOMETRIC AND ELECTRO-OPTICAL SYSTEMS

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ABSTRACT - The results of a reliability and validity study of sagittal plane knee joint angles measured by electrogoniometer and Selspot systems are presented. These angles are found to be linearly related to the true joint angle with the Selspot being more accurate than the electrogoniometer.

RÉSUMÉ - On présente les résultats d'une étude de fiabilité et de validité de la mesure des angles de l'articulation du genou, dans le plan sagittal, à l'aide d'un électrogoniomètre et du système Selspot. On a constaté que ces angles étaient liés linéairement à l'angle de l'articulation vraie et que le système Selspot était plus précis que l'électrogoniomètre.

INTRODUCTION

The measurement of dynamic joint angles is an accepted part of quantitative studies of human locomotion. The protocols and instrumentation used vary widely depending on the preferences and resources of the individual laboratories. Cinematography (1) is a widely used measurement system which requires considerable post-collection effort in digitizing the filmed images. Automatic electro-optical systems which remove the need for digitizing such as the 'Selspot' system are also being introduced(2). Electrogoniometers have long been used as an inexpensive instrumentation system for measuring joint angles in both clinical assessment and research gait studies(3). Given this variety of systems how do we compare the results obtained by different laboratories? Although Stanic et al (4) have discussed the advantages and disadvantages of the above systems, they have not assessed them with respect to their reliability and validity in measuring the joint angles. This paper presents some of the results obtained in a study investigating the reliability and validity of sagittal plane knee joint angles obtained using an electrogoniometer and a 'Selspot' electro-optical system.

MATERIALS AND METHODS

The study was performed on ten normal male subjects ranging in age from 23 to 48 years. The left leg was instrumented using a sagittal plane parallelogram electrogoniometer at the knee joint and infrared transmitters placed over the greater trochanter, centre of the lateral femoral epicondyle, fibular head and lateral malleolus. Knee joint angles were measured with the subject standing while supported at the pelvis and foot by suitable aids. Measurements were made with the knee positioned at five nominal angles: 0,30,45, 60,and 75 degrees. The subject was then reinstrumented and the sequence repeated. Each angle was measured manually by two experienced physiotherapists, each measurement followed by concurrent Selspot and goniometric data collections, and an x-ray taken of the knee area including femur and tibia. Data collections were performed by a PDP 11/34 computer system and were for 1.25 sec at 80 Hz. The data were digitally low pass filtered at 10 Hz and the minimum, maximum, mean and standard deviations of the angles calculated.

RESULTS

There are two sources of error in measuring joint angles, those that result from the inaccuracies of instrument itself, and those that result from the attachment of the instrument to the body.

Selspot and electrogoniometer accuracy and reliablity were first measured using test patterns with the same dimensions as for the human experiments. Test angles from 0 to 90 degrees were measured with both systems using the above experimental parameters. System noise resulted in a maximum range of one degree at each angle setting with a maximum error of one degree from the test angle. Long term stability and reliability were assessed by repeating the measurements one hour later with 20 sec collection periods. The results indicate no short or long-term drift in the systems.

For the ten subjects, the maximum difference between the two Selspot and electrogoniometric measures for each joint angle was found to be two degrees, indicating the subjects did not move during the measurement process. The difference between manual measures of the joint angle was usually less than three degrees with the maximum difference being six degrees. For this paper, the average of the two manual measurements is considered the 'true' joint angle. The relationship between the electrogoniometric and Selspot results and the manual measurements of the joint angles was investigated using regression analysis. Figure 1 shows the results obtained for one subject. This figure shows that the relationships between measured and 'true' angles are linear with the Selspot angles being more accurate or valid. These results were consistent for all ten subjects. Figure 2 shows the relationship obtained for the entire sample for the electrogoniometer angles. This relationship is highly linear (r=.98) with a slope of .72 (ideal = 1) and intercept -.5 degrees. Figure 3 shows similar linear results for the Selspot angles (r=.99) although the slope is .91 and intercept 0 degrees.

CONCLUSIONS

Both measurement instruments were found to be valid and reliable in measuring angles. When applied to a subject the measurements were found to be reliable, that is repeatable but not completely valid. The electrogoniometer results, as expected were less valid than the Selspot results but both systems provided angles that were a linear function of the true joint angle. The inaccuracies in the measured joint angles are obviously caused by soft tissue deformation and movement over the skeleton. The goniometer which is attached by two straps would therefore be more affected. However, these results do not preclude the use of electrogoniometers in measuring joint angles. The linear relationship obtained can be used as a bio-calibration curve to transform the measured angle to a more valid estimate of the true angle. Similarly they can be used to compare normal or pathological values obtained using these two measurement systems.

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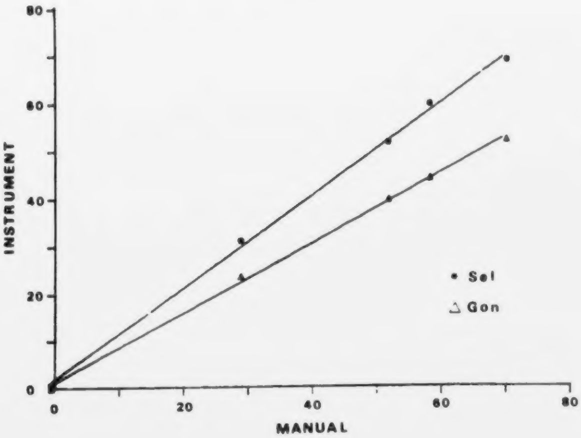

Figure 1

ACKNOWLEDGEMENT

This research was supported by Grant MA-6331 from the Medical Research Council of Canada.

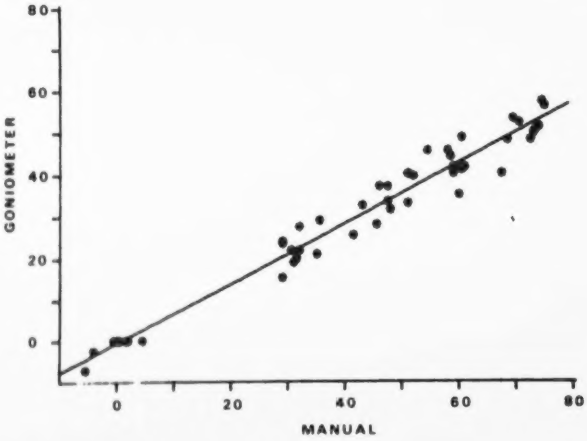

Figure 2

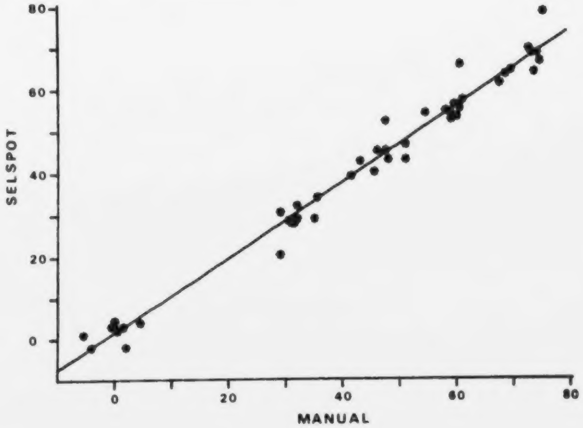

Figure 3

QUANTITATIVE EVALUATION OF SPASTICITY IN CEREBRAL PALSY CHILDREN

Wen Ling Ph.D., James Pugh Ph.D. and Arthur J. Nelson Ph.D.(Bioengineering Department,
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ABSTRACT - This study examined the quantitative muscle activity and resistance to passive stretch of the elbow flexors of spastic cerebral palsy children. The results showed that a low linear correlation (0.18) existed between the quantitative muscle activity and the resistance to passive stretch.

RÉSUMÉ - Cette étude a examiné de façon quantitative l'activité musculaire et la résistance à l'élongation passive des fléchisseurs du conde dans un groupe d'insuffisants moteurs cerebraux. Les résultats ont demontré une légère corrélation (0.18) entre l'activité musculaire quantifiée et la résistance à l'élongation passive.

Over half of the patients with cerebral palsy exhibit spasticity of one or more extremities. Spastic muscles show increased resistance and motor unit activities during passive movements. Various techniques have been used to evaluate spasticity. This study examined the relationship between the quantitative muscle activity and resistance to passive stretch in the spastic elbow flexors with a new technique.

A computerized electromyography (EMG) telemetry system was used to measure the quantitative muscle activity. The EMG telemetry system consisted of a preamplifier, transmitter, and receiver for each channel. As constituted, it enabled two muscle groups to be recorded simultaneously. Each preamplifier had three built-in surface electrodes. A torque sensor mounted on the Cybex II dynamometer, with preset speed of 120 degrees/second, was used to record the resistance of the spastic elbow flexors to passive extension. The simultaneous analog outputs from the EMG telemetry system and the torque sensor were initially digitized by a eight-bit microcomputer. These data were first stored on diskette and later transferred to the VAX 11/750 mainframe computer for analysis. The area under the curve and zero crossings were calculated for the EMG data. The torque data measured during the same interval were also calculated. Figure I is an example of the output from the EMG telemetry system.

Ten cerebral palsy children were tested for reliability. The preamplifier was placed on the muscle belly of the elbow flexors. Their forearms were strapped to the rotating shaft of the Cybex II dynamometer. The subjects were instructed to relax. The immediate test-retest reliability of the quantitative muscle activity is 0.83. The immediate test-retest reliability of the resistance to passive stretch is 0.95.

Twenty-eight cerebral palsy children, ranging in age from one to eleven years with spasticity in one or both upper extremities, were tested. The data were analyzed by the Pearson correlation coefficient program in the Statistical Packages for Social Sciences (SPSS). The results showed a low correlation (0.18) between the quantitative muscle activity and the resistance to passive stretch of the spastic elbow flexors.

In this study, the chief advantage of using the preamplifier with built-in surface electrodes is the extremely low noise level. The receiver of the EMG telemetry system has six band-pass filters further lowers the noise level of EMG signals. The computerized data acquisition system provides better resolution than those presently-available recorders. Also, the data analysis can be performed quickly by the computer.

The findings from this study indicated that the gamma and alpha motoneurons influenced the spastic muscle differently. A further study elucidates the factors involved in determining the degree of spasticity is currently in progress with this experimental equipments and techniques.

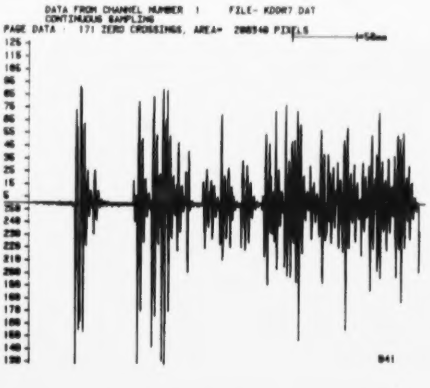

Figure 1 Quantitative EMG Outputs

BIOMECHANICS SIMULATION OF SURGICAL CORRECTION OF SCOLIOSIS

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ABSTRACT - Our effective scoliosis correction technique entails combining distraction with segmentally applied lateral traction. The paper describes the spinal finite-element model's unique clinical application in determining the in vivo spinal stiffness and in prescribing optimal surgical correctional modality.

RÉSUMÉ - Notre très efficace technique de correction des scolioses conjuge la distraction à la traction latérale appliquée par segment. On décrit ici l'unique application clinique du modèle aux éléments finis de la moelle épinière qui a permis de déterminer la rigidité in vivo de la moelle et de prescrire la modalité optimale de correction chirurgicale.

BACKGROUND AND SCOPE

Combined Distraction and Lateral Traction (D & LT) system (as shown schematically in figure 1a) appears to provide better correction than distraction alone for equivalent force levels (1). In some cases, the D & LT system is reinforced by a curvature-rectifying (Luque type) rod attached to the convex side of the spine (as shown schematically in figure 1b).

For an optimal approach to surgical correction of scoliosis, it was deemed desirable to biomechanically simulate the set of corrective forces applied by alternative internal fixation systems, so as to determine and apply the internal fixation system producing the best correction, while ensuring that the forces applied by the fixation systems do not exceed the fracture strengths of the spinal structures to which they are attached.

A method is presented here for (1) determining the stiffness of the spine prior to surgery, and (2) computerized analysis simulation of alternative internal correction-fixation systems, so as to determine the most efficacious custom tailored system.

SPINAL FINITE-ELEMENT MODELING

In the spinal finite-element model, the spine is idealised as a finite element structure, wherein the motion segments are represented as connected deformable beam elements. The nodes of the beam elements are the vertebral centroids. Each beam element has three degrees of freedom at each node, namely two orthogonal displacements and rotation in the scoliotic plane. The bending stiffness of each finite element reflects the stiffness of a motion segment in the scoliosis plane. The spinal finite-element structure is assumed to be hinged at the sacral end and free to move axially at the cervical end according to depicted spinal deformations.

DETERMINATION OF THE STIFFNESS OF THE PATIENT'S SPINE

Known quantities of traction are applied to the patient's head through a special head halter device. The real pull on the body, by the applied traction, is checked with a weighing scale under the foot of the patient. Incremental levels of traction are applied and the spine is radiographically imaged at each incremental level.

Now it is known that the scoliotic spine, analysed as a finite-element model, undergoes large deformations under corrective forces. Also its constitutive properties are nonlinear. However, our spinal finite-element model is linear. Hence, in order to simulate the nonlinear behaviour of the spine in response to corrective forces, the latter are to be applied in small increments, so that for each incremental set of forces the response of the spine is linear.

The data on incrementally applied traction levels along with the associated spinal geometries, is fed into our finite-element model of the spine, and by an inverse analysis the distributed spinal stiffnesses are obtained. The values of the spinal model elements' moments-of-inertia (I) are taken to be those of cylindrical elements, having dimensions of the motion segments. However, since the value of E is obtained by applying corrective forces to the spinal system as a whole, the bending stiffness (EI) represents the local stiffness of the spinal complex and its attachments.

Figures 2 demonstrate, for typical patients, the successive spinal geometries following application of incremental traction forces, and the computed distribution of the spinal stiffness property. At this stage, the spinal finite-element model is patient simulated, and ready to be employed for simulation of surgical correction modality.

FINITE-ELEMENT SIMULATION OF SURGICAL CORRECTION

For surgical simulation of the patient-simulated finite-element model of the spine, a set of corrective forces are to be applied corresponding to a particular fixation system, and the deformation response of the spine is to be determined, using the simulated spinal model's modulus property obtained from the traction test as indicated in the previous section.

For this purpose, small incremental sets of corrective forces are applied to the scoliotic spinal model geometry, and the linear deformation responses of the spinal finite-element model is computed, using the finite-element model, with the up-dated spinal geometries and patient-simulated modulus property obtained from the traction test. This procedure is repeated until the values of the applied corrective forces reach half the fracture values of the spinal structures to which the forces are applied.

The surgical simulation results are presented (along with the presurgical x-ray) in figures 3, for the subject studied in figure 2. The figure depicts the successive corrections achieved by the spinal finite-element model of subject (43), by repeated application of a set of corrective forces corresponding to the D & LT system. It is noted that a 46% correction was gained at the stage where the total (superimposed) force system consisted of 270 N distraction and 180 N lateral traction. It is this level of corrective force system that was decided to surgically implement. This decision was based on the total distraction force and the total lateral traction force not exceeding half the fracture forces of the lamina and spinous processes, respectively, thereby affording a factor-of-safety of 2.

Figures 4 depict comparisons (for the same subjects studied by the traction test) between the corrected spinal configurations following surgery with those predicted by the finite-element modelling for equivalent corrective force levels. It is noted that the predicted segmental deformations of the spine by finite-element model simulation are within 10% of the actual deformations obtained during surgery.

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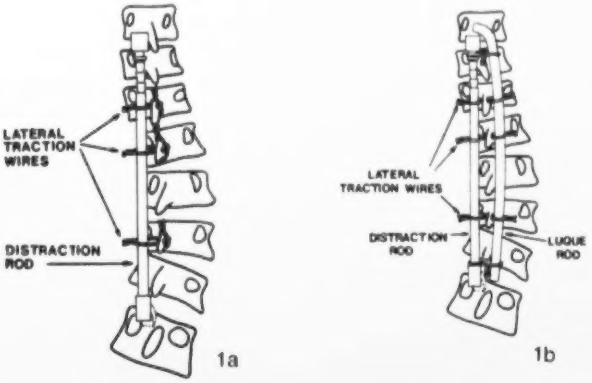

Figure 1: Schematics of internal-fixation systems of the scoliotic spine.

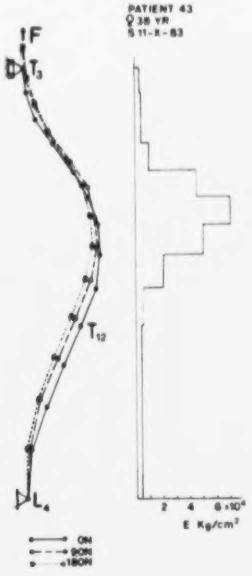

Figure 2: Spinal stiffness determination by the finite element model.

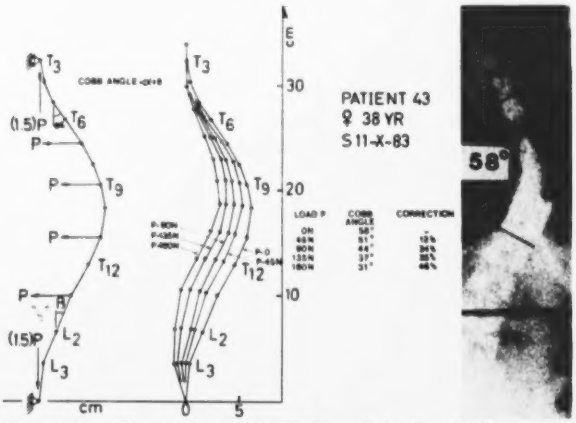

Figure 3: Biomechanical FEM model, simulation results and pre-operative x-rays.

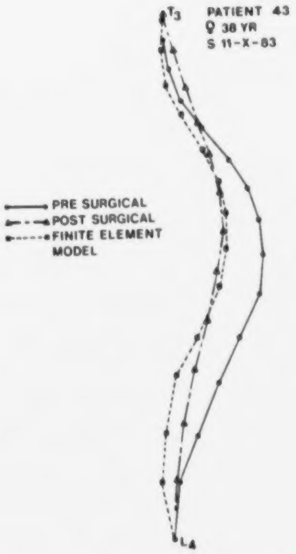

Figure 4: Comparison of the model simulation-based correction with the surgically derived correction.

ASSESSMENT OF RHEUMATOID HAND WEAKNESS

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ABSTRACT - The paper presents the development and clinical evaluation of indices, for sensitively assessing rheumatoid arthritic hand incapacitation and its diurnal variation, based on measurement of dynamic grip strength, by means of a pressure-transducer based system.

RÉSUMÉ - La présente communication expose l'élaboration d'un système d'indices et son évaluation clinique. Ces indices sont proportionnels au manque de sensibilité des mains arthritiques rhumatoïdes et à la variation diurne de cette sensibilité. On les détermine en mesurant la force de préhension dynamique avec un transducteur manométrique.

I. BACKGROUND & SCOPE OF THE PAPER

Rheumatoid arthritis produces overall weakness in the affected hands, influences hand grip and pinch contractility, capability to exert maximal grip and pinch force, and to sustain them. It is also known that this rheumatoid hand function weakness or incapacitation has diurnal variation. Hence if sensitive indices can be developed to adequately quantify this diurnal variation of hand function incapacitation, they could in turn be employed to quantify the efficacy of anti-inflammatory drugs in controlling and reducing this hand incapacitation, through a manifestation of decrease in the diurnal variations of these indices.

A variety of instruments, including spring dynamometers calibrated tensionmeters, torquometers, strain gauges, and mercurial ergonometers have been introduced over the past century and a half to measure grip strength, but none have been proven to have any advantage over the Davis bag or sphygmomanometer. However, grip strength, as determined by the sphygmomanometer, has been found to be relatively insensitive to change with anti-rheumatic medication as well as to diurnal variations.

We have hence developed a device designed to monitor dynamic grip strength, and proposed hand incapacitation (or weakness) indices (based on dynamic measurement of grip force) for characterizing diurnal changes in rheumatoid arthritic hand function incapacitation.

The indices are evaluated for thirteen rheumatoid arthritic patients at the Chedoke division of Chedoke-McMaster Hospitals. The sensitivity of these indices in emphasizing diurnal changes in rheumatoid arthritic hand incapacitation is depicted.

II. DEVICE DEVELOPMENT & INDICES FOR RHEUMATOID HAND INCAPACITATION

In order to monitor the dynamic hand-grip pressure developed by a rheumatoid hand, a simple instrumentation system is developed. This system consists of a pressure transducer, which is designed to provide a DC output voltage, and is linearly proportional to the applied pressure. The pressure transducer has an LVDT to sense the pressure.

This pressure transducer is attached to a hand grip bladder. The electrical output of the transducer is processed through a signal conditioner, and then made to drive an X-Y/t recorder. A sphygmomanometer is also attached to the pressure transducer so that the pressure transducer could be calibrated. A schematic of the instrumentation system is shown in Figure 1.

The following indices have been designated and patient evaluated to characterize the degree and intensity of hand incapacitation due to rheumatoid arthritis:

DMGFR = Rates of maximal grip force between afternoon and morning

DMGCR = Rates of maximal grip power between afternoon and morning

DWC = Rates of grip work capacity between afternoon and morning

An index value greater than one implies greater capacity to exert maximal grip force or power or grip in the afternoon than in the morning.

III. CLINICAL DATA ACQUISITION

In this study, thirteen patients (9 females, 4 males, of ages between 54 and 73 years, and of disease duration ranging from 3 to 40 years) with definite or classical rheumatoid arthritis, as defined by the diagnostic criteria of the American Rheumatism Association were monitored. Figure 2 is typical of the rheumatoid hands assessed. The instrumentation set-up (Figure 3) was wheeled into the ward, to the patient bedside for collecting the data.

Two sets of measurements were carried out, one in the morning before 9 a.m. and the other after 12:30 p.m. For each measurement, the patient was seated either on a wheel chair or on bed, and asked to grip the bladder as hard as possible, and to then endeavor to maintain this maximal grip pressure as long as possible.

The signal output from the signal conditioner was recorded on a chart, using the X-Y/t recorder. The complete grip pressure profile (i.e., the rise of grip pressure, maximal grip pressure achieved, and the decay due to fatigue) was recorded for both left and right hands. The time duration over which the patient's grip was maintained varied form patient to patient, and the average was about twelve seconds. This time-duration did not influence the values of the hand incapacitation indices.

IV. DATA ANALYSIS & RESULTS

The grip-pressure time curves (Figure 4) for each patient, were digitized, fed as input to McMaster University Cyber 170/185 mainframe computer, and stored as indirect permanent files for further processing.

A computer programme in FORTRAN 77 has been developed to analyze the data. This computer programme extracts, from the digitized data, the values of the maximum grip strength (Pmax), time to attain the maximum grip strength, the rate of grip strength development (Power = dP/dt), and the work done, for each hand of the patient and for morning and afternoon measurements.

For these patients, the traditional classification of rheumatoid arthritis, does not provide a sensitive measure of hand incapacitation. On the other hand, Figure 5 shows the values of these indices, obtained from the right hands of thirteeen rheumatoid patients studied at Chedoke Hospital. It is noted that for the majority of these patients the values are significantly greater than one, depicting severity of hand incapacitation in these patients. Having established the sensitivity of this technique, we are now in a position to apply it for drug trials.

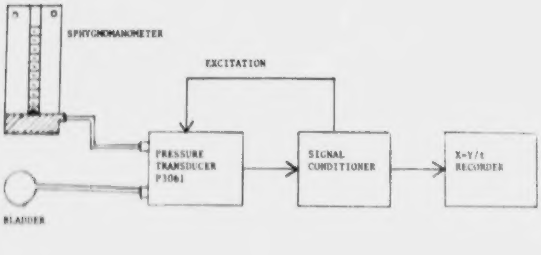

Figure 1: Schematic of Instrumentation Set-up to Monitor Dynamic Hand Grip

FIGURE 2: TYPICAL RHEUMATOID HANDS

FIGURE 3: INSTRUMENTATION SET UP

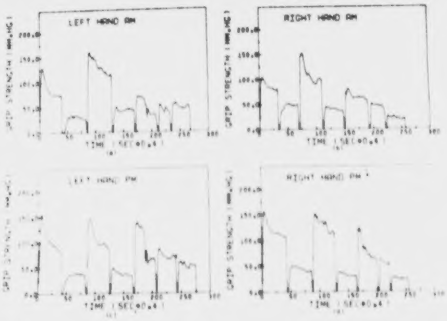

FIGURE 4: COMPUTER PLOTS OF GRIP STRENGTH VS TIME FOR SEVEN SUBJECTS

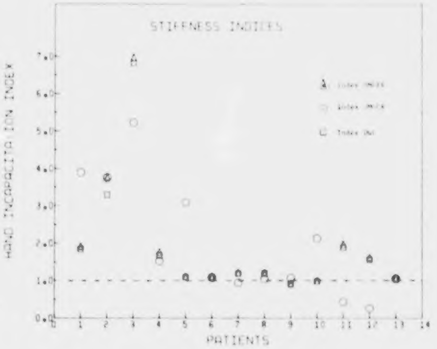

FIGURE 5: HAND INCAPACITATION INDICES

HIGH-FIDELITY REAL-TIME FORCE ESTIMATION FROM EMG

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ABSTRACT - A new processor for EMG has been developed using state-of-the-art microprocessor technology. This device is shown to be almost five times faster than a conventional processor with the same force estimation accuracy. A prominent feature of the new processor is its ease of calibration.

RÉSUMÉ - Un nouveau processeur d'EMG (électromyographie) a été élaboré; il offre tous les avantages de la technologie actuelle des microprocesseurs. Ce dispositif est cinq fois plus rapide que le processeur classique tout en ayant la même précision d'estimation de la force. Une qualité essentielle de ce processeur est la facilité avec laquelle on peut l'étalonner.

The electrical activity of muscle, or EMG as it is more commonly called, is clearly related to muscle force; however, many attempts to process EMG and use it as an indicator of muscle force have suffered from large amplitude, low frequency variations superimposed on the desired output. Elimination of this "noise" is a difficult task -- if the rectified EMG is filtered enough to remove this "noise" component, the time response of the resulting force estimate is unacceptably slow for most tasks (e.g., use as a signal for control of active prostheses or monitoring of muscle force for clinical purposes). Based on a mathematical model of the statistical properties of EMG, Hogan [1] derived the optimal estimator of muscle force and demonstrated its performance in off-line processing of prerecorded data. This technique for processing EMG has now been implemented in a real-time digital myoprocessor using state-of-the-art microprocessor technology [2]. In experiments requiring real-time estimation of muscle force from measured EMG, this processor has achieved substantial improvements over the conventional single-channel myoprocessor.

The basis of the processing technique is the hypothesis that the large amplitude, low frequency "noise" contaminating conventional myoprocessor output is a spatio-temporal sampling artifact caused by the limited pickup region of conventional differential electrodes. Elimination of this artifact requires an increase in sample size, which is accomplished by combining multiple channels of myoelectric activity into a single estimate of muscle force. The optimal myoprocessor algorithm has two major stages: a calculation of the total variance of all of the myoelectric signal channels contributing to the estimate of muscle force and a subsequent inversion of the static relation between variance and force.

The statistical performance of this and other myoelectric signal processors can be estimated from the following simple design relationship:

$$\mathrm{SNR} = \sqrt{4\ B\ T\ N} \qquad (1)$$

where: SNR = signal-to-noise ratio
B = signal bandwidth
T = processing time
N = number of channels

The signal-to-noise ratio (SNR) is defined as the mean value of muscle force divided by the RMS error in force. This terminology stems from the constant force case in which any variation of the force estimate about its mean can be considered as "noise".

In the present implementation of the optimal real-time digital myoprocessor, four differential pairs of surface electrodes are applied to each muscle group under consideration. The electrode outputs are sampled digitally and the resulting signals are mathematically rotated into the coordinate frame in which they are independent, appropriately scaled, recombined, smoothed by time averaging, and converted into an analog signal for output. This myoprocessor is capable of sampling two sets of four electrode pairs at a rate of 1 kHz to generate estimates of the muscle force from two independent muscles.

The performance of this myoprocessor relative to the conventional single-channel analog myoprocessor can be predicted using Equation (1). As the central feature of EMG processing is the trade-off between smoothness and timeliness of the myoprocessor output, it is interesting to compare performance of the optimal myoprocessor and the conventional single-channel myoprocessor on the basis of each of these characteristics. First of all, if the processors are chosen such that the two have outputs with equal rise time, the following approximate relationship describes the improvement in SNR for the optimal myoprocessor:

$$\text{SNR improvement ratio} = \sqrt{\frac{3}{2}N} \qquad (2)$$

where: N = number of channels for
the optimal myoprocessor

Four channels of myoelectric activity contribute to each estimate of muscle force in the present implementation of the optimal myoprocessor, hence the expected improvement in signal-to-noise ratio is 2.4, while incurring no decrease in the processor response time. On the other hand, if the two processors are set up to have outputs with equal SNRs, the following relationship between the rise time of the two myoprocessors results:

$$\text{rise time improvement ratio} = \frac{3}{2}N \qquad (3)$$

where: N = number of channels for
the optimal myoprocessor

Thus for the same RMS error in force estimate, the four-channel optimal myoprocessor is predicted to be a factor of 6.0 faster than the conventional single-channel EMG processor.

The performance of this device was measured by processing the myoelectric activity of a human subject holding a series of weights. EMG from the biceps was simultaneously processed by the four-channel optimal processor and a conventional single-channel myoprocessor with the same response time. Typical results are presented in Figures 1 and 2; the new device is clearly superior. In preliminary experiments, the average measured SNR improvement ratio was 2.2, close to the theoretical prediction. Alternatively, if the processors had been set up to have equal SNRs, the optimal real-time processor would be almost five times faster than the conventional single-channel processor.

A major drawback of the earlier off-line implementation [1] was the tedious, time-consuming calibration procedure required. In the present implementation, this problem has been completely eliminated. A calibration algorithm has been incorporated in the processor which executes in approximately one second, providing virtually instantaneous recalibration to readily accomodate changes in operating conditions such as electrode shifting and muscle fatigue. This self-calibration feature considerably enhances the applicability of the device and will facilitate the transfer of this new technology into clinical and laboratory use.

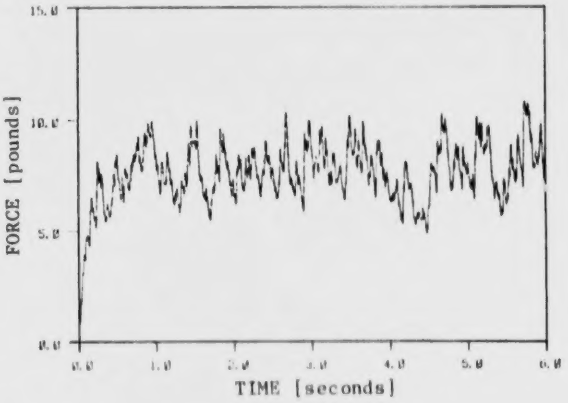

Figure 1. Conventional Single-Channel Myoprocessor Performance

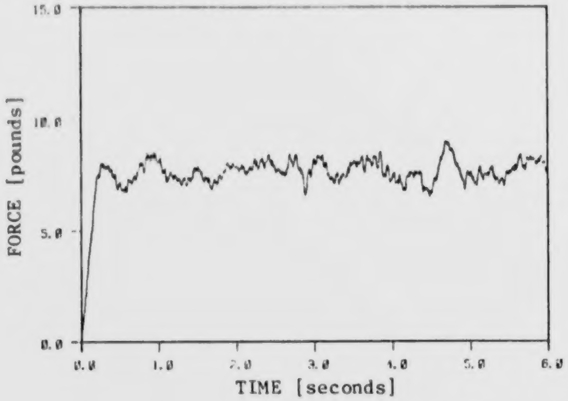

Figure 2. Optimal Four-Channel Myoprocessor Performance

ACKNOWLEDGEMENT

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AN ON-LINE MULTICHANNEL ELECTROMAGNETIC GONIOMETER FOR MEASURING HAND MOVEMENTS

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ABSTRACT - An electromagnetic goniometer system for recording hand movements is outlined. Euler angles of finger segments may be determined using small magnetic field sensors. In a prototype system a resolution of 0.1 degree and an accuracy better than 2% was obtained. The system is non-contacting, simple to use and may be appropriate for clinical assessment of joint function.

RÉSUMÉ - On décrit un goniomètre électromagnétique pour l'enregistrement des mouvements de la main. On peut déterminer les angles d'Euler de segments de doigt à l'aide de petits détecteurs de champ magnétique. On a obtenu un pouvoir séparateur de 0,1 degré et une précision supérieure à 2% avec un prototype de l'appareil. Il s'agit d'un système sans contact, facile à utiliser et pouvant éventuellement servir à l'évaluation clinique du fonctionnement des articulations.

There is a recognised need to develop improved movement recording methods for clinical functional assessment of the hand (Boyes, 1980). For example, Kay (1981) resorted to the use of a schoolroom protractor in preference to hand held goniometers or Odstock wires. Kay considered static joint range of motion to be the most useful of the available measures for objective assessment of joint function.

The following measurement techniques have been developed for research purposes. However they are not suitable for clinical use. Multi-axis electrogoniometric systems have been reported, (e.g. Ebskov 1966). However these systems would appear to be too cumbersome for multijoint free range motions. Photographic methods using bi-lateral radiographs, single frame and cine film have been applied for 3-D spatial measurement (Kai-Nan et.al.1983, Purves 1980). These systems are restrictive because of the delays in obtaining results and the effort required in digitising the films. Opto-electronic and spark-gap sonic digitiser systems have been used to automate the spatial data acquisition (Erdman et.al.1979, Youm et.al.1979, Brumbaugh et.al.1982). Spatial measurements are restricted by line of sight requirements between source and sensor. In addition, the number of skin mounted components required for 3-D multi-joint analysis becomes cumbersome.

An electromagnetic goniometer system has been developed for motion analysis of the hand. This system may be suitable for clinical use. The principle of operation is illustrated for 2-D in figure 1. Two spatially orthogonal Helmholtz pairs are driven by the phase quadrature currents Ia and Ib. The resulting magnetic field vector is circularly rotating in a clockwise direction at a frequency ω. The planar magnetic field sensor is shown inclined at an angle ϕ. The induced sensor voltage will be proportional to $\cos(\omega t - \phi)$. The angle ϕ may thus be directly determined using a phasemeter.

For 3-D a third, mutually orthogonal, Helmholtz pair is added to form a cage of coils as shown schematically in figure 2. The coil system is driven using three quadrature oscillator (S.G.)outputs so as to generate three, spatially orthogonal, field vectors rotating at frequencies $\omega_1, \omega_2, \omega_3$. If a hand mounted magnetic field sensor is positioned within this cage a signal will be induced having components at the three rotating vector frequencies. The phase of each component with respect to the corresponding field vector will be directly proportional to the orientation of the sensor with the generating coil system axis. The Euler angles of the sensor relative to the triad axis system of the coil cage can be determined directly by phase difference measurements.

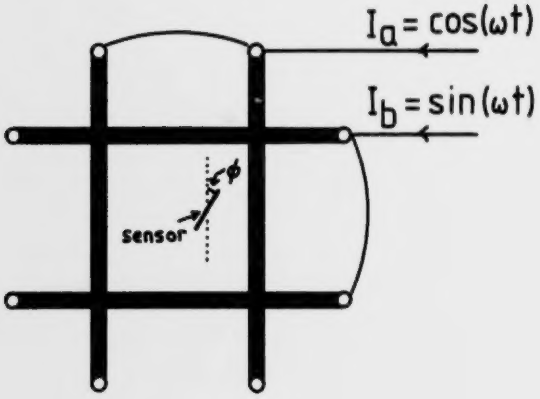

Figure 1. Principle of Operation.

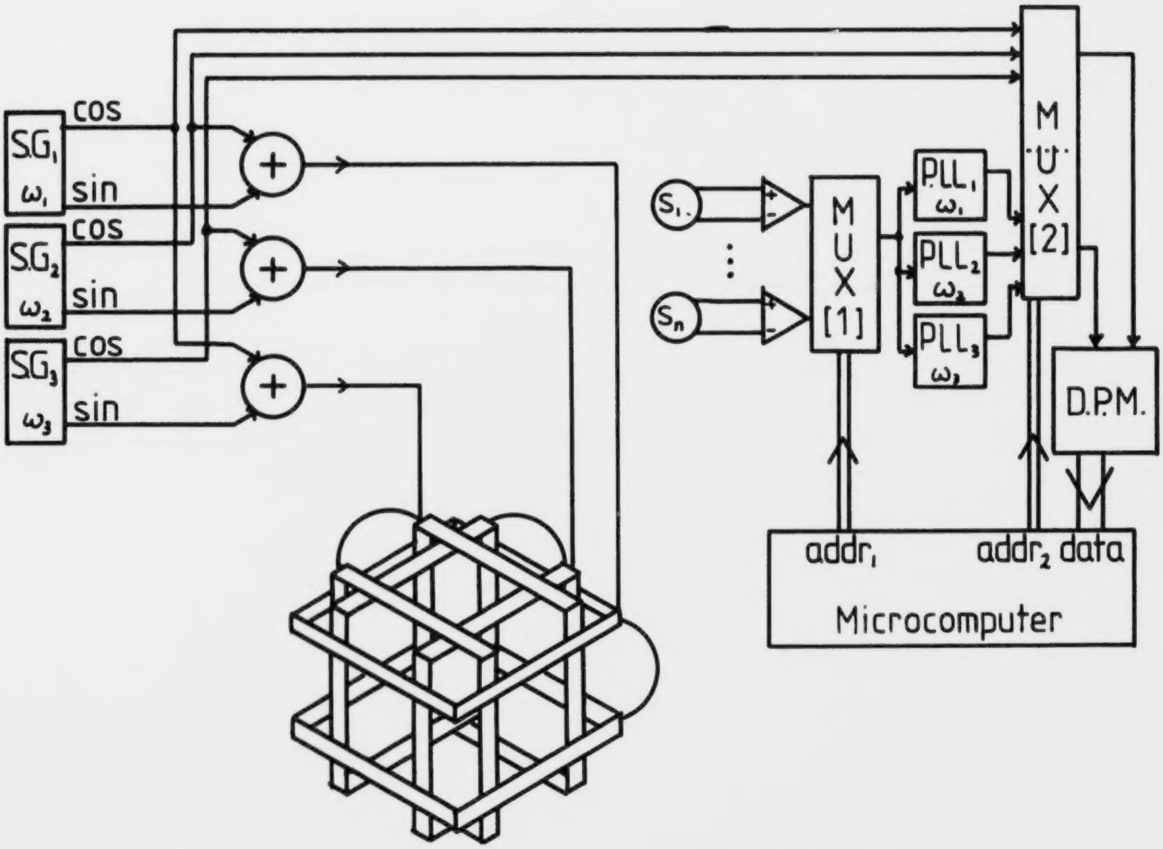

Figure 2. Schematic Diagram of the On-line Electromagnetic Goniometer System.

Multiple sensors can be accommodated by multiplexing the induced signals as indicated in figure 2. The sequence of phase measurements is as follows. The computer selects a sensor by establishing MUX1 address lines (addr1). The phase locked loops (PLL) then lock onto the sensors three component frequencies. The computer routes each of the three components, in turn, together with the corresponding reference, through the differential multiplexer MUX2 to the digital phase measuring circuit (D.P.M.). The sequence is then cyclically repeated for each of the sensors.

Miniature sensors may be constructed using Hall effect devices or small coils attached onto suitable mounts. These sensors may then be affixed to dorsal aspects of finger segments using double sided adhesive tape.

A prototype system was constructed using square Helmholtz coils (0.7m). A resolution of 0.1 degree and linearity better than 2% was obtained within a measurement volume of a 320mm cube in the center of the coil cage. The coils were driven at frequencies between 15-30 kHz producing magnetic fields having flux densities typically 1.5×10^{-4}T. The prototype had 8 sensors (overall dimensions of 12×10×1.5mm). The three euler angles were sampled for each sensor at a rate of 125 Hz.

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MECHANICAL TESTS OF SPINAL FIXATION DEVICES

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ABSTRACT - The following describes a scheme for the mechanical evaluation of spinal fracture instrumentation. Harrington distraction rods, Harrington compression system and segmental spinal instrumentation were evaluated. The criterion for evaluation was the movement permitted at the fracture site relative to a nonfractured region.

RÉSUMÉ - La présente communicaton dévoile une technique d'évaluation de la tenue mécanique du matériel de traitement des fractures de la colonne vertébrale. Les tiges de distraction de Harrington, le système de compression de Harrington et l'instrument segmental de la colonne ont fait l'objet d'une évaluation. Le critère d'évaluation retenu est le déplacement relatif à l'endroit de la fracture par rapport à la région intacte.

Background and Relevancy:

Unstable thoracolumbar spine fractures present both immediate and late management problems. Treatment of the patient by early ambulation has promoted an aggressive surgical approach to stabilizing the spine. Although the aim of operative intervention is well documented, the actual instrumentation used varies considerably: Harrington distraction, Harrington compression, Weiss springs and titanium mesh and Luque's Segmental Spinal Instrument (SSI) are but a few of the choices available.

There appears to be a proliferation of designs with no means available to compare the efficacy of each design. Late angular deformity is a common problem because inadequate fixation allows movement around the fracture site delaying healing. These problems have led investigators to devise testing schemes for the evaluation of different designs.

The experiments generally involve loading the instrumented spinal model to failure. Although this approach provides a means to evaluate the ultimate strength of the system, it does not lend itself to an evaluation of the behaviour of the system under normal load levels. In particular, no information can be obtained as to how well the instrument has limited the movement of the fracture site. It is vitally important that any instrument used for the fixation of spinal fractures minimize movement of the fracture site if the conditions for healing are to be optimum and if the risk of complications are to be minimized.

Objective of Study:

The purpose of this study is to determine the efficacy of Harrington distraction rods, Harrington compression rods and Segmental Spinal Instrumentation, in protecting a spine with a compression fracture at L1 under low levels of load.

Prototype Fracture:

Mature sow spines removed intact from freshly slaughtered animals and immediately frozen were chosen as the experimental model. The anatomical structure of the sow spine closely resembles that of the human. The T9-L5 segment of sow spine was excised and thawed. A 0.75 cm. groove was created in the anterior body of L1 making it most prone to failure. The spine was then enveloped at the ends by two cylindrical aluminum sleeves and subjected to an increasing compressive load using an Instron universal testing machine until a marked drop in the load deflection curve was observed. Observation and roentgenograph verified that fracture of the L1 body had occurred.

A total of 13 spines were prepared and fractured in this manner after which each was ready for the application of a fixation device.

Fracture Instrumentation:

The spines were instrumented, tested, instrumented again with a different fixation device and retested. In this manner each type of instrumentation was tested eight times, four times when it was applied first, and four times when it was applied second. This procedure allows each spine to act as its own control.

Testing Procedure:

With normal activity the major load acting on the spine is eccentric compression, a combination of forward flexion moments plus axial compression. The spinal column itself is sensitive to torsion. For these reasons the following three types of loads were applied to the spinal segments: a) axial compression, b) torsion, c) compression bending (flexion moments).

Compression loading required no special equipment. Solid caps were placed on the end of the aluminum sleeves and the spine held in the Instron using simple adaptor brackets. The fractures were stressed to approximately 50% of fracture load. After completion of the compression test, the solid upper end cap was removed and a torsion bracket attached to the aluminum sleeves. The spine was fixed at the bottom and pinned at the top preventing all but rotational movement. Pure torsion was applied to the instrumented spine in 2.6 Nm increments to a maximum of 10.4 Nm.

A compression bending test was the final test performed on each device. A knife edge attachment to the Instron was placed in a notch in the upper end cap providing a 2.5 cm. lever arm.

A photographic technique was utilized to record the motion of the instrumented spine as it was loaded. Three aluminum rings were attached to separate vertebral bodies. The upper two rings were mounted in the instrumented region and had a normal disc and a normal vertebra between them (normal region). The lower two rings encompass a normal disc and a fractured vertebra (fracture region). The rings provide an attachment point for screws used as markers to follow the motion of the spine during testing. On all rings the markers were positioned at 90° to each other, equidistant from the centre of the ring.

Measurement of spinal motion utilized a method consisting of two cameras to photograph the spine from views 90° apart. This allowed monitoring of spinal motion in any direction. Two tripod mounted Nikon 35 mm cameras were used. The motor drive of each camera was connected to a common switch to facilitate simultaneous firing of both cameras from one location. These photographs were synchronized with load application.

Data Analysis:

All information was retained in the form of 35 mm glass mounted slides. The translation of the photographic information to true physical positions was accomplished with the aid of a computer. Approximately 2000 photographic images were obtained and analyzed. For each set of photographs pertaining to a specific instrumented spine and load configuration, two datum points and nine marker points were digitized. Four position variables were determined: 1) the vertical position Z which is the vertical distance from the datum plane to the centroid of a particular ring; 2) the rotational position, the angle of rotation about a vertical access; 3) the frontal slope; 4) the lateral slope.

Displacements of any of the four position variables relative to the zero load position were determined by calculating the difference between given and zero load positions. This procedure was applied to both views of each ring under all load conditions for all tests.

Changes in vertical, rotational and angular displacements were determined for both the normal and the fractured regions. The difference in the displacements of the two regions provided a measure of the fracture site displacement alone.

Error Analysis:

The following were analyzed as sources of potential error.

1. Data Collection: Spine stiffness and size varied from specimen to specimen. To avoid this problem each spine was instrumented with two different devices permitting the two devices to be compared independent of spinal variation.

   Errors involving camera field foreshortening were minimized by using long (200 mm) focal length lenses.

2. Digitizing: Errors involving cursor positioning during the digitizing process were determined by repeatedly projecting and digitizing a single slide. Horizontal and vertical positions were found to be reproducible to within +/- one mm.

3. Data Analysis: The transformation of two dimensional ring coordinates to the three dimensional ring positions requires two assumptions. The ring markers must be equidistant from the centroid and orthogonal to each other. Measurements showed that the radius was correct to within +/- 0.25 mm and that the deviation from 90° resulted in a vertical or horizontal error of +/- 0.25 mm.

Combining all sources of coordinate error discussed above suggests an uncertainty of approximately +/- 1.285 mm (1.0 for digitizing, 0.035 for foreshortening, and 0.25 mm for ring geometry). This figure is improved upon during the analysis by combining the data from the left and right views.

Results

The tests were carried out in two sets of six spines. Each set produces a comparison of the devices tested for each of the three load configurations.

Observation of the results of the Segmental Spinal Instrumentation (SSI) and the Harrington Distraction system indicate:

1) The two systems showed no significant difference when placed under a compression-flexion load.
2) The SSI performed, to some degree, better than the Harrington Distraction System in supporting a compressive load.
3) In the first set of tests, there was virtually no difference in the performance of the two devices when loaded torsionally. The second test, on the other hand implied that the Harrington Distraction restricted fracture motion to a greater degree.

A study of the tests comparing the Harrington Compression instrumentation and the SSI shows that:

1) Under a compression-flexion load, the performance of the SSI is superior to that of the Harrington-Compression.
2) There was no significant difference in protection of the fracture site under either a compressive or a torsional load.

Finally, comparison of Harrington-Distraction, and Harrington-Compression rods imply:

1) The Harrington-Distraction system provided a slightly greater degree of fracture protection under a compression-flexion load.
2) Harrington Compression rods show a greater amount of fracture fixation under compressive loads.
3) No significant difference in device performance was found in torsion testing.

Two points of interest arose during the tests. First, the stiffness of the normal zone is considerably less for the second test, regardless of the order of application of instrumentation. Correspondingly, only a small change of stiffness occurs in the fractured zone. A possible explanation is the first test introduces soft tissue damage in the normal zone, reducing the stiffness of the body. The deformation of the fracture itself is large, therefore neighbouring soft tissue deformation is not noticeable.

Secondly, some of the results indicate a stiffer fractured region than normal region. This implies that although a fracture is present, it is not unstable. This phenomenon poses the following questions regarding surgery. In some cases which occur clinically, is fixation even necessary? Could more be done prior to surgical treatment to determine the necessity of fixation? This could be the basis of further study.

Conclusions and Future Considerations:

Results to date indicate the following performance characteristics of the three devices:

a) Harrington - Compression and Luque performed similarly in compression tests, both allowing less fracture movement than Harrington - Distraction.
b) No significant difference in device performance was found in torsion testing.
c) Harrington - Distraction and Luque protected the facture equally well in compression - bending tests, both devices showing better performance than Harrington - Compression.

Work in this area is far from complete. Tests are continuing in order to expand the present statistical base. Concurrent with the present tests, improvements in overall procedure are being attempted. In order to eliminate scatter in experimental results caused by dissimilarity between spines, a mechanical model of the human spine is being prepared. Once developed this spinal model will eliminate the need for a large number of tests as the scatter due to spinal differences will be eliminated. This should also provide assurance that the desired injury could indeed be applied to the model. At present the digitizing process is a long and tedious one. With the aid of television cameras, a system which will automatically digitize the spinal position is being tested. This system will eliminate, or reduce, the error involved in the digitizing process, which is the largest source of error at present.

Groups in the U.S. and Mexico have expressed an interest in this procedure and have requested that testing be performed on new devices of their design. In addition preliminary tests have been completed on a spinal fixation device developed at the Glenrose Hospital.

Acknowledgements:

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RESISTIVE TORQUE MEASUREMENTS OF SPASTIC ANKLE JOINT MUSCLES IN HEMIPLEGIA

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ABSTRACT - An equipment for resistive torque measurements of spastic ankle joint muscles is described. The measurements performed with this system indicate the differentiation of hemiparetic patients regarding the tonic and phasic component of the stretch reflex.

RÉSUMÉ - Le matériel pour les mesures résistantes du couple des spasmes musculaires de la cheville est décrit. Les mesures réalisées à l'aide de ce système permettent une différenciation des patients hémiparétiques en ce qui concerne les composantes toniques et phasiques du réflexe d'extension.

During the past twenty years biomechanical measurements were widely used in testing and evaluation of spasticity (1-5). Still there is a great interest for this type of measurement (6,7). It seems that many interesting characteristics of spastic muscles are not enough explained, therefore new findings about stretch reflex activities and other parameters of spasticity can be expected. Different research groups use specific test equipment, therefore the data obtained can not be easily compared. The main operating principles are as follows: machine driven position controlled servosystems (2), machine driven torque controlled servosystems (4), hand driven position controlled systems (3) and gravity driven systems (5). The equipment described in this paper is a hydraulically powered position controlled servosystem (Fig. 1). The position of ankle is measured by means of a precise potentiometer and can be determined with accuracy of ± 0.5 degree. The torque transducer built into the system is able to measure torque with accuracy of ± 0.05 Nm. Two to four channels EMG recording equipment is added to the system for observation of muscle activities during passive and active movements.

Position controlled system has two advantages in comparison to the torque controlled one such as: - initial value of the angle is stable and easily obtained by input signal; - many different types of measurements for quantification of particular components of spasticity are possible with the same equipment. The initial angle is important for those patients who have no voluntary control of tested muscles. Such a biasing is not stable enough in the case of torque controlled system. Beside the conventional measurements such as resistive torque due to slower muscle stretch, hyperactivity of phasic and tonic stretch reflex, the position controlled system enables also clonus testing and measurements of muscle strength and dynamics of voluntary produced torques.

In the case of position controlled equipment two types of measurements are usually performed: a) constant velocity stretching and b) sinusoidal stretching. In our measurements both methods were used. In sinusoidal stretching we measure resistive torque at five frequencies (0.1, 0.5, 1, 1,5 and 2 Hz). At each frequency we usually measure ten periods of oscilations.

Fig. 1: Measurement equipment

The response to sinusoidal stretching at different frequencies enables the differentation between two groups of patients with predominant spasticity in m. triceps surae: patients with characteristic phasic response (Fig. 2.a) and patients with mainly tonic component of stretch reflex (Fig. 2.b). In the majority of patients the antigravity muscles (triceps surae) are spastic but there are also the patients with spastic m.tibialis anterior and m.triceps surae (Fig.3c).

Since the response of resistive torque varies from period to period at each frequency we defined the measure of resistance as a norma of probability vector.

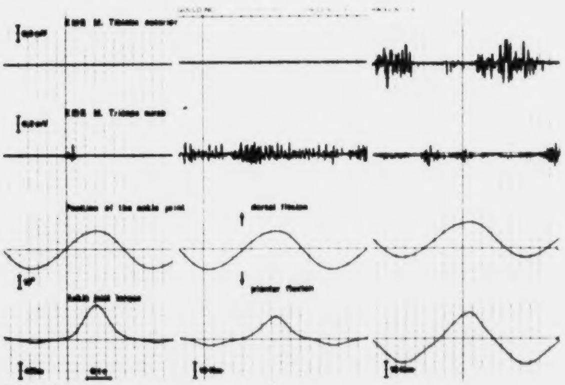

Fig.2 a b c

$R = \sqrt{\sum_i \bar{r}_i^2}$, where $\bar{r}_i$ is the average value of resistive torque at a given frequencies.

$i = 0.1, 0.5, 1, 1.5, 2$ Hz.

An abrupt stretch can be used for eliciting of clonus. After the stretch the ankle is held in a fixed position determined by the hydraulic system (Fig.3). The duration of the clonus and amplitude of torque can be used for evaluation of clonus intensity.

One of the important parameters of spasticity is voluntary produced force or torque and its dynamics. It can be simply measured with the described system, when the foot plate is hydraulically locked at a prescribed position and the patient is asked to produce voluntary force as quick and as much as possible. The system becomes now an isometric torque meter and in Fig.4 the record of such a measurement is shown. The dynamic response of the torque indicated the patients ability for coordinated movement and relaxation. From Fig.4 an extra long time period for relaxation of triceps surae muscle is noticeable, which is related to the spasticity of this muscle.

All measured parametrs indicating spasticity are variable, even when the experimental conditions are kept constant as much as possible. To determine this variability measurements of peak to peak resistive torque due to passive movements at different frequencies have been performed on ten hemiparetic patients. Each patient was tested ten times in intervals of five minutes and the measurement was repeated after one or two months. The results were evaluated on the basis of resistive torque vector and linear regression was used to determine the slope of changing during a 45 minutes time period. It was found that in hemiplegic patients with only phasic active stretch reflex, resistive torque slowly increases with time, while in the patients with both activities its value decreases. The increase or decrease in accordance with the type of spasticity was always consistent, even when the measurements were performed on the same patient after one or two months.

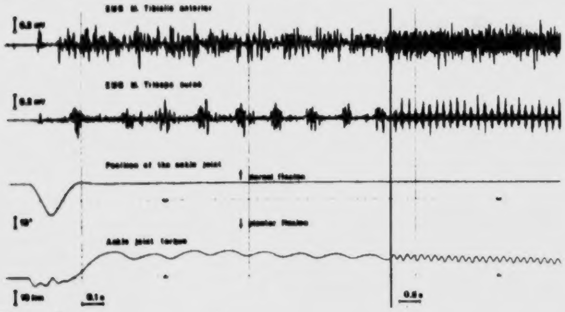

Fig. 3

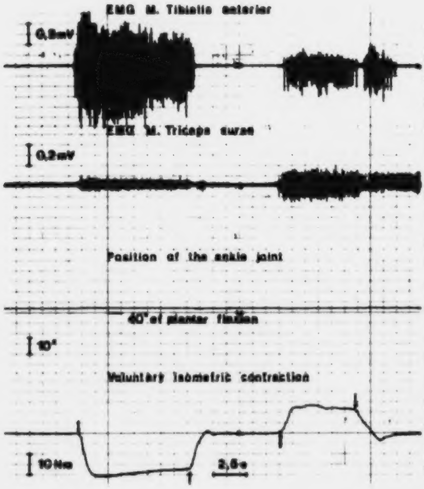

Fig. 4

Hemiparetic patients can therefore be classified into two groups regarding the phasic and tonic stretch reflex activity and their variability characteristics. There parameters could be together with measurements of voluntary control a promising tool for evaluation of different therapy procedures oriented towards modification of spasticity.

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INTRINSIC CURVATURE AND TORSION ASSESSMENT OF SCOLIOTIC SPINES IN FRIEDREICH'S ATAXIA

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ABSTRACT - This paper presents an investigation into the relative curvature and torsion of the scoliotic deformation associated with Friedreich's ataxia. A mathematical model represents the spatial configuration of the spine by means of a quintic spline function. These equations are applied to compute the intrinsic curvature and torsion parameters in order to provide a more thorough description of the changing shape of the scoliotic spine.

RÉSUMÉ - Une étude sur la contribution relative de la courbure et de la torsion dans la scoliose est présentée et appliquée pour les cas d'ataxie de Friedreich. Un modèle mathématique représente la configuration spatiale du rachis à l'aide d'une fonction spline quintique utilisée pour déterminer les paramètres scoliotiques intrinsèques dans le but de mieux décrire les formes évolutives de la scoliose.

It was reported, in a recent study on the biomechanical evaluation of scoliosis in Friedreich's ataxia (Allard et al., 1982), that most of these patients seemed to indicate, at a specific stage of the disease, the occurrence of a relative rotation of the thoracic segment with respect to the lumbar segment of the spine. This observation was assessed by means of a tridimensional reconstruction program using cubic spline functions as well as specially designed devices for standardizing standing and sitting spinal radiographs. From its cubic spline function, the mathematical model computes spatial parameters of a geometric curve based on the location of the centroid of each thoraco-lumbar vertebra obtained from standardized biplanar radiographs (McNeice et al., 1975). One of these parameters is the projected surface area (PSA), defined as the measurement of the virtual surface observed when the spine is projected on a plane perpendicular to the axis formed by superimposing its extremities.

The investigation of the evolution of the spine deformity in Friedreich's ataxia revealed that the PSA index increased considerably more than the Cobb angle. It was thus assumed that a significant torsion might be superimposed on the scoliosis. This hypothesis was confirmed by a simulation of preset torsion of the thoracic spine with respect to the lumbar spine introduced in the geometric curve model (Dansereau et al., 1982). But the simulation developed in that study gives at the most an estimation as to what could be the repartition of the torsion along the thoracic spine. This paper presents a more thorough description of the shape of the spine curve by means of its intrinsic curvature κ and torsion τ, as suggested by Patwardhan and Vanderby (1981). To demonstrate the clinical potential of these parameters, they have been applied here to study the scoliosis evolution of a Freidreich's ataxia patient followed over a 12-month period.

DEFINITION OF THE INTRINSIC CURVE PARAMETERS

The well-known Frenet formulae are utilized to deduce the basic equations to determine the intrinsic $\kappa(s)$ and $\tau(s)$ function of its arc length parameter, s:

$$\frac{d\vec{T}(s)}{ds} = \kappa(s)\ \vec{N}(s),\ \frac{d\vec{B}(s)}{ds} = -\tau(s)\ \vec{N}(s) \ldots (1)$$

which are expressed in terms of the Frenet frame field consisting of the unit tangent vector $\vec{T}(s)$, unit principal normal vector, $\vec{N}(s)$ and unit binormal vector, $\vec{B}(s)$ (O'Neill, 1960). Equation 1 can also be applied to compute the intrinsic curvatures of the spatial curve as observed respectively in the anterio-posterior (κ_{AP}) and lateral (κ_{LAT}) planes.

METHODS

To obtain the numerical values of the spatial curvature and torsion, it is essential that the first to the third derivatives of the cubic spline function be known at each point along the spine curve. Interpolation methods are utilized to then determine the derivatives. Since the cubic splines do not have continous third derivatives, it was necessary to develop an original quintic spline interpolation having an imposed slope at one end of the spine (T1) and a simply supported condition at its other extremity (S1). The details of the implementation of this numerical technique are beyond the scope of this paper.

RESULTS AND DISCUSSION

The determination of these intrinsic parameters was applied to study the evolution of the deformity of a Friedreich ataxia patient followed for a 12-month period (3 visits). Figure 1 shows the evolution of the three curvature intrinsic parameters κ_{AP}, κ_{LAT}, and κ at the patient's first and third visits. The T5 and T11 peaks in Fig. 1A represent respectively the curvature (24° Cobb angle) of the scoliotic spine and of a mild compensatory curve not clinically measurable. At the patient's third visit, the single curve evolved into a double scoliosis of 38° thoracic and of 32° lumbar with an associated increase of the κ_{AP} index. The L2 and T8 peaks observed in Fig. 1B are associated with a lumbar lordosis and thoracic kyphosis. The lower values reported at the patient's third visit reflect a natural tendency towards a gradual progression from a lumbar lordosis to a kyphotic postural attitude leading to the commonly observed kyphoscoliosis in Friedreich's ataxia. The spatial curvature κ, seems somewhat stable over the period of observation. This is due in part, to the combination of increased scoliosis in the frontal plane and of a decrease curvature in the lateral plane.

An attempt was made to extract, from these intrinsic parameters obtained at every point of the spine curve, the most diagnostically relevant information. The following specific parameters were of clinical significance in the scoliotic thoracic region: the maximum curvature of the thoracic spine (κ_{max}), the maximum curvature of its anteroposterior plane projection (κ_{AP}max), the maximum curvature of the lateral plane projection (κ_{LAT}max) and the maximum torsion (τ_{max}). The results are shown in Table I where the evolution of the PSA index was also recorded. The most interesting observations of these results are that:

i) κ_{AP}max has an evolution which can be put in correspondence with the Cobb angle,
ii) κ_{max} represents not only the extent of scoliosis but also of kyphosis,
iii) τ_{max} shows a dramatic increase at the 2nd and 3rd visit.
iv) The PSA index is a very sensitive parameter which responds not only to a change in the thoracic torsion (between 2nd and 3rd visit) as was previously shown (Dansereau et al., 1982) but also to a change in the κ_{LAT}max or kyphosis angle (between 1st and 2nd visit).

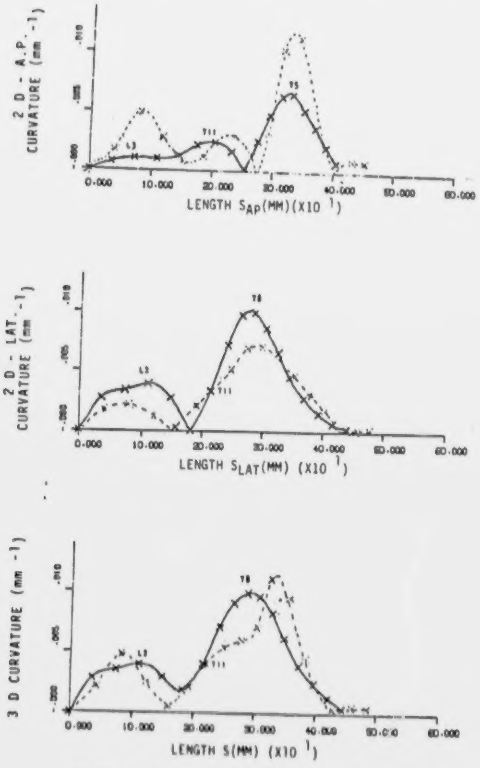

FIGURE 1. Comparison between the first (——) and third (---) visit: a) antero-posterior curvature versus length; b) lateral curvature versus length; c) tridimensional curvature versus length.

CONCLUSION

This paper has shown that the intrinsic spine curve parameters (curvature and torsion) are a powerful diagnostic tool to assess the evolution of scoliosis in Friedreich's ataxia. It is felt that this diagnostic tool should be applied to a larger population of Friedreich's ataxia patients as well as to other cases of paralytic or idiopathic scoliosis.

ACKNOWLEDGEMENTS

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Table I

Clinical data obtained from the three-dimensional analysis of a scoliotic spine as seen in Friedreich's ataxia

Visit	Age	Cobb Angle (degrees)	κ_{AP}max (m^{-1})	κ_{LAT}max (m^{-1})	κ max (m^{-1})	τ max (m^{-1})	PSA
1	16	24	6.7	10.1	10.1	-11.5	1135
2	16½	33	7.1	8.1	7.6	-14.1	1000
3	17	38	11.7	7.1	11.5	-30.9	2100

SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 23

NEURAL PROSTHETICS II - FUNCTIONAL ELECTRICAL STIMULATION/
PROTHÈSES NEURALES II - STIMULATION ÉLECTRIQUE FONCTIONNELLE

CONTROL VARIABLES IN COMPLETE PARAPLEGIC RECIPROCAL GAIT

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ABSTRACT - Complete paraplegic patient walking synthesized by 4-channel FES is described. In order to increase patient's safety during the reciprocal gait a new control principle for electrical stimulators is suggested. It is based on the hierarchical, logical control and artificial intelligence principles. Possible control variables for artificial proprioceptive sensory feedback are also discussed.

RÉSUMÉ - La démarche d'un paraplégique synthétisée par un stimulateur fonctionnel électrique (FES) à 4 canaux est décrite. Pour augmenter la sécurité du patient pendant la démarche réciproque, on propose un nouveau principe de commande des stimulateurs électriques, basé sur les principes de hiérarchie, de commande logique et d'intelligence artificielle. On examine aussi des variables de contrôle pour une rétroaction artificielle mettant en jeu les propriocepteurs.

INTRODUCTION

Only in few rehabilitation centers some selected and adequatelly trained complete paraplegic patients with lesions in thoracic region, are able to walk with the help of functional electrical stimulation /1,2,3,4,5/. Several stimulation techniques have been reported and different stimulating sites have been used /2,3,5/. It seems there still remains an unsolved problem - it is patient's safety during gait. Because of the lack of balance and stability a complete paraplegic patient can not walk without an arm support(e.g. parallel bar, roller-walker, walking frame or crutches). Some assistance from attendance (therapist) is also required to increase patient's safety and to prevent possible hazardous situations. To make walking paraplegic assistance free it is necessary that stimulator itself together with patient assumes the responsibility for his safety. It means that stimulators as multichannel generators of stimulating pulses should be replaced by smart stimulators where simple and effective control algorithms should be implemented.

BACKGROUND

In Ljubljana complete paraplegic patient's reciprocal gait is synthesized by using four channel surface FES. The simple gait pattern is divided into swing phase of left leg, double stance phase and swing phase of right leg. During double stance phase both knee extensor muscle groups are stimulated. The swing phase is realized through excitation of flexor synergistic response by a single stimulation channel. It is left to the patient to control the stimulator by using push buttons, hidden in the handles of a walker or crutches, to initiate a transition from double stance to swing phase.

So far, biped walking has been restored in five complete paraplegic patients. One of them, having T-5 to T-7 complete spinal cord lesion is shown in Fig. 1. His walking has been analyzed through electrogoniometers, measuring the knee joint angles and force shoes, measuring the reaction forces. The results of the gait analysis are presented in Fig.2. Values of the knee joint angle are very repeatable during each gait cycle and can be used to determine whether the swing or stance phase is performed in the given time. The angle Ø is a continuous variable with two characteristic values determined experimentally:

$\O = 0^{\circ} \pm d\O_E$ *- during knee extension, and*

$\O = 30^{\circ} \pm d\O_F$ *- during knee flexion*

The vertical ground reaction force component can be transformed into a discrete, binary information, introducing treshold level of vertical force or simply detected by ground contact sensors. Different in-sole switches with adjustable ON-OFF characteristics mounted on three foot zones can be used for that purpose giving 3 bits of information.

Fig.1: Paraplegic patient with goniometers and force shoes

Binary values of four hand push button switches together with both values mentioned above form "state vector". Having this in mind the reciprocal stationary gait on level ground can be considered as the sequences of successive events, each being described by the state vector. All control variables are easily measurable and the corresponding signal can be introduced into a simple controlled (microcomputer). Its function is to determine the desired discrete value of knee joint angle for each lower extremity in every gait cycle and to prevent collapsing of the leg.

Some attempts have been made to solve knee joint angle problems with a classical close-loop control. It has been proved that single linear controller can not accomplish efficiently the control task in both stance and swing phase. Therefore the authors decided to apply hierarchical, logical control which basic aspects are described in /5/. For this purpose the hierarchical system "patient-stimulator" was decompositioned into four levels:

I. patient's commands
II. level of logical decision
III. stimulator electronics
IV. controlled lower extremities.

Level I and II are implemented in microprocessor based 4ch stimulator (MC 146805E2) where some knowledge of gait is presented and stored in memory (EPROM) in form of production rules already established in artificial intelligence approach. Gait cycles are performed on the basis of vizual feedback information, patient's commands, artificial proprioceptive sensory data and one of control algorithms automatically selected according to the state vector.

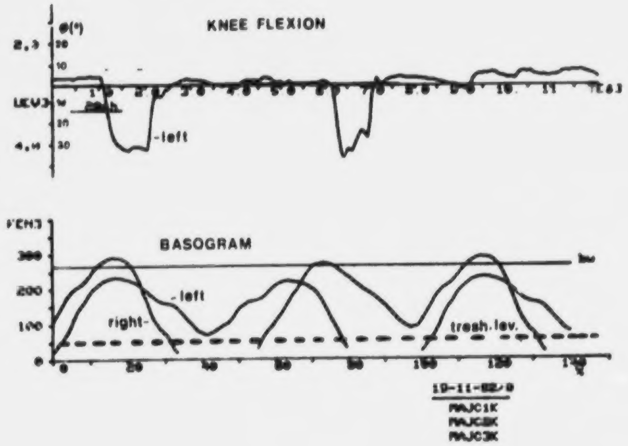

Fig.2: The results of the complete paraplegic gait analysis:
- knee joint angle ø(°) versus time T (upper trace)
- vertical ground reaction force F (N) versus normalized average stride time (lower trace)

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A SYSTEM FOR SELECTION OF MODULATED CONTROL SEQUENCES FOR FUNCTIONAL ELECTRICAL STIMULATION:
I. AN OVERALL DESCRIPTION

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ABSTRACT - Functional control of the lower extremities by electrical stimulation utilizes a stored preprogrammed set of control sequences. A laboratory-based system is described that will permit an operator to select modulated sequences to actuate the limbs in precise, coordinated movements.

RÉSUMÉ - Le contrôle fonctionnel des membres inférieurs par stimulation électrique fait appel à un ensemble de séquences de contrôle préprogrammé et mémorisé. On décrit un système expérimental permettant à un opérateur de choisir des séquences de modulation pour faire effectuer aux membres des mouvements précis et coordonnés.

Introduction

Electrical stimulation has been used to activate appropriate muscles of the lower extremities during ambulation to improve the quality of walking in persons with neuromuscular impairment.[1-4] Until recently, control has been "on-off"; i.e., stimulus parameters are held constant during each period of stimulation. Stanic et al[5] showed that improved performance could be achieved by modulating stimulation to produce a graded response in the stimulated muscles--in their case, the ankle dorsiflexors. Even greater improvement in walking quality can be expected by using modulated control of the larger muscles of the hip and knee.

Selection of modulated control sequences to optimally assist a person with neuromuscular impairment during walking is far from trivial. Models of bipedal gait are not accurate enough to generate the desired control by computer simulation. This means that appropriate control sequences must be determined experimentally in the laboratory for each individual. A system that has been recently developed to accomplish this is described in this and the following paper. The overall operation and a block diagram is presented in this paper. Technical details of the system are described in the following paper.

System Description

A block diagram of the system is shown on the next page. The heart of the system is a Cromemeo System One microcomputer. Control sequences stored in memory can be used to directly control any number of stimulation channels through output modules 1-N. Muscle force is modulated by controlling the amplitude or duration of each pulse in the stimulation train. Each output module can be connected to a pair of cutaneous or percutaneous electrodes. The stored sequences can also be used to program stimulators implanted inside the body. Programmable, battery-powered multichannel stimulators are now being developed by Pacesetter Systems, Inc., a major cardiac pacemaker company, and our system has been designed to be compatible with their stimulators.

Control sequences stored in the microcomputer are easily altered. The stimulation envelope of the channel of control to be changed is displayed on a Modgraph GX100 graphics terminal screen, and the desired change is drawn on the screen by moving the screen cursor with a Houston Instrument Hi Pad digitizing pad. When the operator is satisfied with the change, the old control sequence is replaced in memory with the new control. An Epson FX80 graphics printer can be used to obtain a hard copy of all of the control sequences at any time.

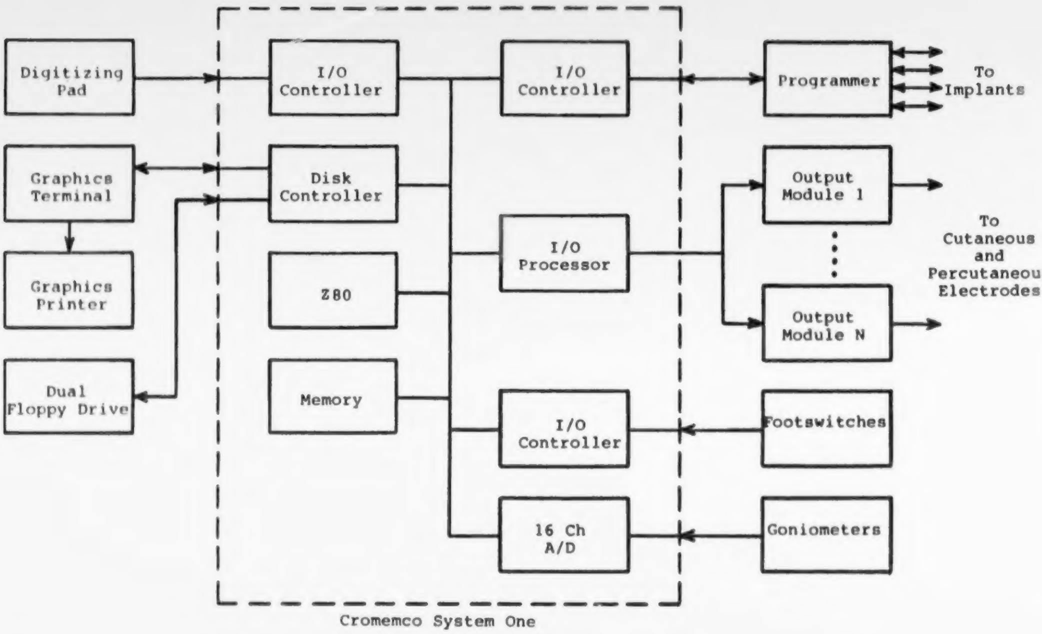
Walking performance is documented by electrogoniometers placed on the hip, knee and ankle and by footswitches that monitor foot/floor contact at the heel, first metatarsal, fifth metatarsal and toe. These data, averaged over one walking trial, can be displayed on the graphics terminal superimposed with the control sequences. A video system and an electromyographic recording system, though not shown in the block diagram, are also available for use on selected walking trials.

Averaged footswitch and goniometric data from any trial can be stored on floppy discs along with the control sequences used on that trial. This will permit us to easily return to a previous control set if subsequent changes lead to a degradation in walking performance.

System Operation

Given a set of control sequences, the patient will be asked to walk with the aid of electrical stimulation along a 10m walkway. The investigative team, consisting of a clinician with extensive experience in bipedal ambulation and an engineer who is knowledgeable in functional electrical stimulation, will determine what changes should be made in the control sequences to improve walking performance. This decision will be made by observing the patient while they

BLOCK DIAGRAM OF PROGRAMMING SYSTEM


Digitizing Pad
Graphics Terminal
Graphics Printer
Dual Floppy Drive
I/O Controller
Disk Controller
Z80
Memory
I/O Controller
I/O Processor
I/O Controller
16 Ch A/D
Programmer
To Implants
Output Module 1
Output Module N
To Cutaneous and Percutaneous Electrodes
Footswitches
Goniometers
Cromemco System One

are walking and correlating these observations with the goniometric, footswitch and, when necessary, electromyographic data. Changes to the control sequences are implemented using the graphics terminal and digitizing pad as described above. The patient is then asked to walk again with the assistance of the new set of control sequences. This trial and error process is continued as long as necessary (generally over several days of testing) until satisfactory performance has been achieved.

Initial estimates of the control sequences can be obtained in one of two ways. One method is to simply "draw" a priori sequences on the graphics terminal based upon electromyographic records from normals and from ambulatory patients with similar neuromuscular impairments. A second method is to have a physical therapist trained in electrostimulation select appropriate on-off controls for the patient by adjusting the stimulus amplitude, delay from trigger and duration of stimulus train for each stimulation channel. This procedure is done routinely at our hospital with multichannel stimulators used clinically for gait training. When the "best" set of stimulation parameters has been determined by the therapist, they are programmed into the computer and used as a starting point for determination of the modulated sequences.

This system provides a fast, efficient way to alter many channels of stimulation during repeated walking trials with patients having neuromuscular impairments. The availability of such a system is imperative in selecting control sequences that will make a significant difference in the quality of walking for these individuals.

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A SYSTEM FOR SELECTION OF MODULATED CONTROL SEQUENCES FOR FUNCTIONAL ELECTRICAL STIMULATION: II. A SYSTEM HARDWARE DESCRIPTION

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ABSTRACT - The design of a laboratory computer-based stimulation system with graphics capabilities is described. A host/slave processor arrangement and a unique set of output modules which generate stimulation signals make this a powerful controller for use in functional electrical stimulation research.

RÉSUMÉ - La conception d'un système informatique de stimulation en laboratoire doté de caractéristiques graphiques est décrite. Une configuration maître/esclaves des processeurs et un ensemble unique de modules de sortie qui génèrent des signaux de stimulation font de ce système un outil puissant de commande dans la recherche sur la stimulation électrique fonctionnelle.

Introduction

The reasons for utilizing sophisticated hardware such as a computer in a portable laboratory stimulation system are ease of use in the definition of parameters of complex stimulation waveforms, the ability to employ methods of digital filtering and mathematical analysis, and an easily attained expansion of the system. The addition of stimulation channels and the capability of handling complicated control algorithms for the eventual likelihood of the closed-loop control of functional electrical stimulation (FES) are very desirable features not easily attained in traditional stimulation systems. What precipitated the departure from non-computer based stimulation systems for our work was the necessity of changing variables of stimulation for a single pulse during a train of pulses for modulating the stimulation of a motor group being used in movement control studies.

System Description

The Rancho Laboratory Stimulator uses a Cromemco System One computer as the host processor. This S-100 bus system has a Zilog Z80A microprocessor, sixty four thousand bytes of random access memory (RAM), a custom sixteen channel twelve bit analog to digital converter (ADC), two floppy disks, a graphics terminal emulating a Tektronix 4010, a digitizing tablet and a graphics printer. The host processor is responsible for: the generation of interactive video graphics for use in the definition of stimulation envelopes and other parameters of stimulation; the generation of data lookup tables corresponding to those stimulation parameters so determined; data acquisition and storage; and communication with a slave processor.

The slave processor is another Z80A microprocessor which is responsible for controlling specially designed output modules. This arrangement, host and slave, allows each processor to have a full complement of memory and, more importantly, frees the host from the time consuming responsibility of directly controlling the output waveforms for each of the stimulation channels.

In the generation of stimulus waveforms in a microprocessor-based system the most obvious approach to take is to have the microprocessor directly controlling the output of a stimulus channel by means of an input/output (I/O) port and a digital to analog converter (DAC), and timing the duration of the various levels of DAC output using software timing loops or programmable timers. Although this is a rather straight forward approach, it is very costly to the processor when the number of channels is increased or when the waveforms become more complex. This approach places great demands on the microprocessor's attention since it will likely be responsible for more than just waveform generation.

Because of the inherent problems of the above approach, we decided that it would be more prudent to design a system employing two processors, one to govern overall system performance and a slave processor to handle just waveform generation. To further reduce the overhead to the slave processor and to alleviate the need for supervision during the generation of a biphasic stimulus waveform, intelligent output modules were designed.

The slave processor board chosen was the Input/Output Processor (IOP) from Cromemco. This board consists of a Z80A microprocessor, sixteen thousand bytes of RAM, space for thirty two thousand bytes of programmable read only memory, and an external data, address and control bus with which it can control devices such as output modules, more memory or other computer peripherals. The slave processor receives its program and operating instructions as well as the data tables used in the stimulation process over the S-100 bus of the host processor.

The output module which is controlled by the slave processor is a very capable piece of hardware, requiring only basic information about the waveform pulse parameters and a software trigger to start the pulse. Since the host computer uses the very popular S-100 bus, it was decided to design the output module to reside on a single card for the S-100 bus and to adapt the external bus of the IOP to the S-100 bus as well. The output module is a memory mapped device and thus looks like an ordinary set of memory locations to the processor. This allows the full complement of memory-referenced instructions of the Z80A microprocessor to be used with the device. The module's base address is switch selectable to reside on any 256 byte page in memory, allowing a large number of these modules to be used in a system.

The output module consists of four main sections: five twelve bit wide data latches corresponding to the pre-stimulus current amplitude, positive phase of the biphasic waveform current amplitude, interphase interval amplitude, negative phase amplitude, and the post-stimulus current amplitude; six programmable sixteen bit timers, four of which are used for the duration of positive, interphase, and negative phase intervals and the inter-pulse intervals; timing and control logic; and a twelve bit multiplying DAC and buffer amplifier. The module can thus be set up by the slave processor with the amplitude corresponding to the five phases of the stimulation waveform by storing twelve bit numbers in the five latches, resulting in one in 2047 amplitude resolution, the length of time for each of the three pulse phases with one microsecond resolution in three of the sixteen bit timers and the length of the inter-pulse interval in the fourth timer. In addition, a vectored interrupt may be generated at the conclusion of any of the above intervals, allowing extremely fast response by the Z80A slave microprocessor to an end-of-pulse or end-of-period event.

Once these values are stored on the module, the microprocessor has only to do a memory write to a location on the board to trigger a stimulus pulse set to occur. All timing, gating, and control functions required to retrieve the twelve bit latch information and regulate the operation of the timers are performed on the module with no need for processor supervision. Additional pulses can be triggered by simply writing to the start location again.

The advantages of such a host/slave system with essentially intelligent output modules are that the addition of channels will require only minor modifications to control algorthms and only minor increases in processor time overhead. Each channel addition would entail the insertion of another S-100 bus output module card, setting its address to a unique page in memory and providing it with the proper attention in the operating system. Because the output modules are S-100 bus compatible, it is feasible to use these modules in a number of applications and computer systems. In our application, the host processor receives information concerning the patterns of stimulation to be applied by each channel via the graphics terminal keyboard and a digitizing tablet and displays the information corresponding to a stimulation sequence in a gait cycle on the graphics screen. Linear and non-linear curve smoothing will modify the data until the researcher is satisfied with the results, after which the host will generate data tables from this information which will be given to the slave processor over their common S-100 bus communication link.

During stimulation, the host will not be idle but will be using a custom sixteen channel ADC to acquire information from goniometers, and an I/O port to acquire footswitch information for triggering stimulus events. The sixteen channel ADC can acquire a twelve bit number in only six microseconds and can place the result in either a left or right justified sixteen bit word. Left justification is particularly useful during a control situation where accuracy is not as important as fast response. This makes it possible to use only the most significant eight bits of a left justified result as a pointer in a data table lookup algorthm. Right justified results lend themselves directly to math operations requiring twelve bit accuracy. But in either case, no shifts or rotates of the twelve bit result are necessary to get the data in the desired format.

The ADC operates by receiving two bytes of information: a channel number and format code in the first byte and a start command in the second byte. The reason for using two bytes was to allow the result format to be changed without initiating another data conversion. The six microseconds are almost transparent to the processor and only one or two dummy instructions need to be executed to wait long enough for the ADC data to be valid.

The above described system should prove to be an exceptionally powerful and flexible tool in our research for several years. The power of computer graphics and high level software languages such as Fortran will enable an ease of parameter definition heretofore unseen in a laboratory stimulation system. The speed of the slave processor and output module design coupled with assembly language control algorthms will allow numerous channels of output control while the host is free to acquire data and modify information used by the slave processor such that real time closed-loop control could eventually become a reality.

Acknowledgement

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GAIT PATTERN BEHAVIOUR OF HEMIPLEGIC PATIENTS UNDER THE INFLUENCE OF A SIX-CHANNEL MICROPROCESSOR STIMULATOR IN A REAL ENVIRONMENT

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ABSTRACT - In this paper the application of a new six-channel microprocessor controlled stimulator on a small group of hemiplegic patients is described. The data provided by this device are represented in diagrams and some changes of gait pattern are shown.

RÉSUMÉ - L'article décrit un nouveau stimulateur à six-canals contrôlé par un microprocesseur. Ce stimulateur a été appliqué à un groupe de patients hémiplégiques. Les résultats obtenus avec cet appareil sont démontrés par les diagrammes présentés dans l'article, de même que plusieurs changements de qualité de la marche.

INTRUDUCTION

Use of multichannel electrical stimulators is one of the most promising trends in the physical part of the rehabilitation of patients with plegic or paretic extremity muscles. Lesions usually result in the loss, diminuition or disorganisation of control over some muscles, although the muscles themselves remain capable of contracting under artificial electrical stimulation. Using stimulation of six major muscle groups in the leg (in the saggital plane), a higher degree of improvement is achieved in a shorter period of time compared with classical methods of physical therapy (1).

The aim of this paper is to describe the microprocessor controlled interaction between a handicapped person and a machine. The results of this interaction are a shorter rehabilitation time of the patient, and generation of a certain amount of data that describe patients gait and are very important for later analyses. An example of such data and their representation is also given in this article.

INSTRUMENTATION

Previous six channel stimulators (2,3) were constructed on the basis of various analog and digital techniques. These structures were not flexible enough, or capable of offering satisfactory solutions to the ever growing demands for control of the stimulation. For such applications, the use of a microprocessor is much more convenient, and, supported by appropriate hardware and software, promotes much better therapy and at the same time control of the course of the therapy, which is very important for later analysis of the therapy (6). All these options are included in the new six channel microprocessor stimulator (5); (Figure 1).

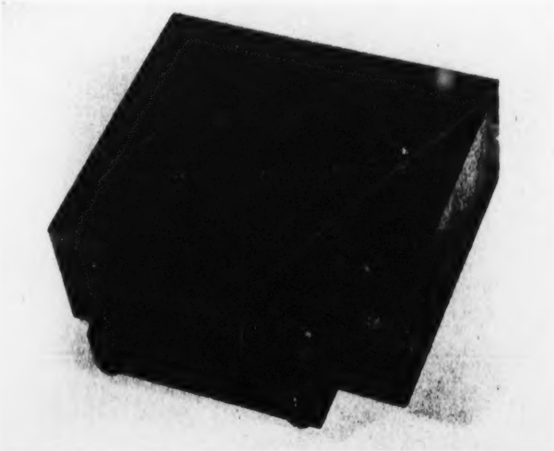

Fig. 1 Six-channel microprocessor stimulator

This stimulator has six independent channels triggered by a left or right insole heelswitch. The stimulation sequence is set for each channel with 16 switches, 8 for the stance and 8 for the swing phase. The polarity of the electrodes can be changed for each channel by a switch. Four stimulation sequence sets can be stored or recalled from the memory on demand. After therapy, statistical parameters are available for display: the number of steps, the symmetry of gait, the average stride time, and for each leg, the average heel-on phase time with its standard deviation. The stimulator operates in two modes: a) cyelic in which the duration of the sequence is preset on a cycler; the walking rate dependant - the duration of the sequence is calculated by the software (5), depending on the history of gait.

This stimulator has two very important advantages. The walking rate dependant mode is designed to follow all changes of the patients gait, to help the patient by stimulation without disturbing him. The second advantage is that we can follow the course of rehabilitation of the patient in his natural environment, because if we analyse gait in the gait laboratory, the patient might be psychologically influenced and the data will not be representative of the patient.

METHODOLOGY

Hemiplegic patients were treated according to our experience with classic six channel stimulators (4). Six muscle groups were stimulated in the following order:

Channel 1: n. peroneus
Channel 2: m. triceps surae
Channel 3: flexors of the knee
Channel 4: m. quadriceps
Channel 5: m. gluteus max.
Channel 6: m. triceps brachii

First we try to find the stimulation spots on a patient in the standing or lying position, so as to get maximal contraction of the desired muscle group and an optimal movement. The stimulation sequences are initially set in a preliminary way (example in Figure 2) and are changed later according to the patient˝s gait. The amplitudes are set one after another during gait. The patient walks as long as he is able to (up to 2500 steps), or as long as the doctor prescribes (up to 500 steps), depending on his medical condition. The patient usually walks through the corridors of the rehabilitation centre, but sometimes we even take him out to walk around the building. Eweryday when therapy is over, we display all the statistical parameters mentioned above and write them in a special form. This form also includes the stimulation sequences, amplitudes, triggering and polarities, so that all these parameters are easily set before the next application on the same patient.

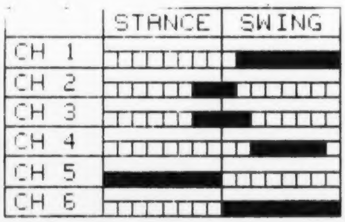

Fig. 2 Stimulation sequence set

RESULTS

So far, we have treated four patients with the six-channel microprocessor stimulator over periods of 49, 23, 15 and 2 days. Figures 3, 4 show typical courses of measured parameters for one of the patients mentioned above. Figure 3 (right diagram) shows the course of the average stride time and we can see that it shortens from day to day (it changes for ca. 20% through the therapy). The symmetry is improving, as shown in Figure 3 (left diagram), but oscillates for unknown reasons to the other side at the end of therapy. The diagrams in Figure 4 show the course of the average heel-on phase time (stance time) for the left and right leg with their standard deviations. The dotted line represents variability. The stance phases also become shorter and the standard deviations smaller through the therapy, and therefore the variability also goes down. These diagrams show us that the gait pattern of the patient improved quite well in a very short time. We can say the same for the second and third patient, but there is not enough data for the last patient, who was stimulated only twice.

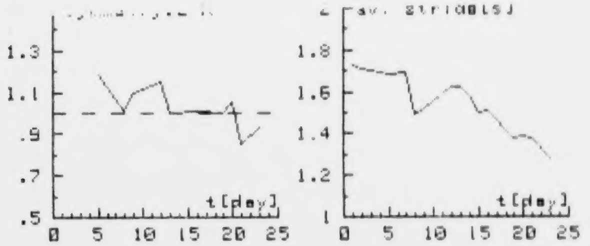

Fig. 3 Diagrams of the symmetry of gait and average stride time

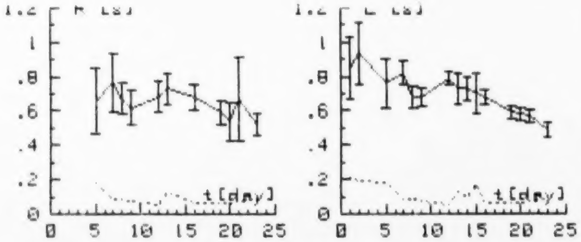

Fig. 4 Diagrams of the stance phase times

From these results we may conclude that we have a very successful and useful orthotic aid for rehabilitation of hemiplegic patients for clinical use, and on the other hand, a measuring device that provide us with a sufficient amount of data to follow the course of rehabilitation of the patients, without being the measuring equipment in the gait laboratory.

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A PORTABLE MICROPROCESSOR CONTROLLED IMPLANTABLE FUNCTIONAL NEUROMUSCULAR STIMULATION SYSTEM

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ABSTRACT - A small portable functional electrical stimulation system has been developed. The system consists of a flexible programmable microprocessor based external controller/transmitter unit and an eight channel radio frequency powered and controlled implantable stimulator unit.

RÉSUMÉ - On a mis au point un petit système de stimulation électrique fonctionnel portatif. Le système se compose d'une unité de contrôle/transmission externe gérée par un microprocesseur programmable souple et d'une unité de stimulation implantable alimentée et commandée par radiofréquence à huit canaux.

BACKGROUND

We have developed a portable percutaneous stimulation system for functional neuromuscular stimulation (FNS) of the hand (1). The systems are used by outpatients for control of prehension and release. This system provides both stimulation and control functions which duplicate those generated by our laboratory system (2). Chronically indwelling percutaneous electrodes presently are utilized, but they are intended primarily as an interim solution, to be replaced by a totally implantable stimulator (3). As well as eliminating the percutaneous interface, the implantable stimulator is designed to increase the number of output channels available, thus providing a more flexible stimulator system.

MATERIALS AND METHODS

A functional block diagram of the implantable FNS system is given in Figure 1. The system has three basic sections; the front end controller, the formatter/transmitter, and the implant stimulator.

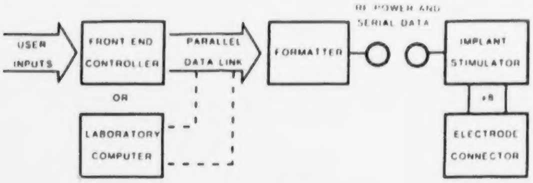

Figure 1. Functional Block Diagram of the Portable Implantable Stimulator System.

Front End Controller

The front end controller is an adaptation of our current microprocessor based percutaneous system (1). The front end controller accepts up to eight analog inputs with eight bits of resolution. Sampling rates of 50 Hz have been used.

Once the input signals have been converted, digital signal processing can occur. The possibilities include digital filtering, pure time delays, deadband and programmable transfer function through the use of lookup tables.

The processed user inputs are used to generate one or more command signals as dictated by a software defined control algorithm. The command signal(s) is then used as an index into a parameter lookup table. These parameter tables contain the pulse width (PW) and interpulse interval (IPI) parameters for each channel and group as described later. Each lookup table contains 256 entries providing a fast, flexible realization of any type of stimulus regime/command signal transfer function.

Stimulation parameters are transferred to the formatter over an eight bit wide parallel interface. There are also three control lines to support the parallel data transfer. The interface and communications protocol is designed in such a way that a laboratory computer may take place of the front end controller in controlling the implant.

Formatter

Communication of stimulus information from the front end controller to the implantable stimulator is carried out through the formatter and the radio frequency (RF) link. The stimulus information received by the formatter is stored in memory, and is used to format commands for the implant stimulator. Unless the stimulus information in memory is updated by the front end controller, the formatter will use the same stimulus parameters to format subsequent commands for the implant stimulator. Thus, the controller need only communicate with the formatter when a change of stimulus parameter occurs.

It is possible to operate the implant stimulator as eight independent stimulus outputs. However, most muscle functions will be the result of several channels of stimulation working together to produce the desired limb response. The information input to the formatter allows the flexible formation of stimulus "groups" (2) ie, one or more stimulus channels that operate at the same interpulse interval. Thus, the formatter is supplied with the following stimulus information, (a) the number of stimulus groups being used with the implant stimulator, (b) the stimulus channels belonging exclusively to each stimulus group, (c) the interpulse interval for each stimulus group, and (d) the stimulus pulse duration for each individual stimulus channel. Stimulus information can be updated as needed by the front end controller, allowing complete modulation of all group interpulse intervals and individual channel stimulus pulse durations.

Implant Stimulator

Through the use of semi-custom integrated circuit technology and thick film hybrid circuit techniques, an implantable muscle stimulator has been developed. The unit is reliable, small, lightweight, has low power consumption, and is intended for permanent useage. The stimulator circuitry is externally controlled and powered by a single, encoded, radio frequency carrier. Up to eight independently controlled stimulus output channels are provided, with output channel selection, stimulus pulse width (variable 0-250 μs with 1 μs resolution) and stimulus interpulse interval (to as low as 20 ms with 1 ms resolution), all under external control. A constant current, biphasic stimulus pulse is used, in which the stimulus current amplitude can be programmed over the range 2-20 mA by a single resistor value.

Command signals are serially input to the implant stimulator via the transdermal RF link. The formatter gates the RF carrier on and off, producing a serial stream of several pulses making up a single command to the implant stimulator. Each command elicits the output of a single stimulus pulse from the stimulator. The command signal designates the electrode to be stimulated and the duration of the stimulus pulse. The rate of repetition of the command determines the stimulus interpulse interval for that electrode.

The stimulator circuitry is encapsulated in a titanium package using multiple metal-glass-metal feedthroughs, and laser welding for hermetic sealing of capsule lid and feedthroughs. Overall package stabilization of capsule, feedthroughs, external RF receiving antenna and electrode lead wires is achieved by epoxy encapsulation. The stimulator design is suitable for use with a variety of different electrode lead terminations.

Five glass-ceramic Macor packaged models of the implant have been surgically placed in animals for functional evaluation. Three devices had subfascial electrodes, two had nerve cuffs. The implants have been functional for up to 11 months.

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32-CHANNEL PORTABLE PROGRAMMABLE STIMULATOR FOR WALKING OF PARAPLEGICS

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ABSTRACT-A portable microprocessor-controlled stimulator was developed for use with percutaneous intramuscular electrodes to provide paraplegic patients with a simple control over their individualized stimulation patterns for walking. Using this stimulator paraplegics were able to walk up to 15m in parallel bars or with a walker for additional support and balance.

RÉSUMÉ-Un micro appareil de commande stimulant contrôle a été developpé pour l'utilisation d'électrodes intra-musculaires percutanées (injectées) afin de procurer aux malades paraplégiques un contrôle simple sur leurs modes de stimulations individualisés. En utilisant ce stimulant, les paraplégiques etaient capables de marcher jusqu'à 15(quinze) metrès sur les barres parallèles ou bien a l'aide d'un déambulateur pour un support ou balance supplémentaires.

INTRODUCTION

Application of electrical stimulation with surface electrodes has reduced atrophy (1) of disused paralyzed muscles to enable paraplegic patients to stand up and walk (2). However, positioning of surface electrodes to obtain reliable selective contractions of deep muscles is difficult. This problem has been overcome by use of cuff (3) and intramuscular electrodes (4,5). A portable microprocessor-controlled stimulator is described which can be used with percutaneous intramuscular electrodes by paraplegic patients for exercising, standing up and walking.

SYSTEM SPECIFICATION AND IMPLEMENTATION

Specifications for the stimulator were based on the following factors. First, the stimulation parameters should be within the safe limits, but capable of producing adequate forces to accomplish desired tasks. Second, the number of available channels of stimulation should be commensurate with the minimum number of active muscles required to produce walking in normal individuals. Third, the stimulation pattern to produce artificial walking should be easily controlled by the patient and adjusted to his needs. Further, the stimulator should be portable and easy to don.

Biphasic balanced-charge constant current pulses of 20mA with pulse width modulated from 0 to 150 microseconds at a frequency of 25 Hz were found to be within safe limits (6) and capable of eliciting muscle contractions sufficiently strong to produce artificial walking in paraplegic patients (7). Pulse width was modulated to control the force of muscle contraction (8).

The authors estimated that 32-channels of stimulation would be sufficient to provide a paraplegic patient with functional walking. This was based on the activity of muscles during normal walking and on our previous experience of stimulation of paralyzed muscles (9). The following muscles were considered for stimulation bilaterally. Three channels were assigned for knee extension; one to recruit the whole quadriceps, and two for the vastus medialis and lateralis. Hip flexion could be produced by either the iliopsoas alone or in combination with the tensor fasciae latae, sartorius, and gracilis, thus requiring a minimum of four electrodes or channels. Stimulation of the gluteus maximus, posterior portion of the adductor magnus, and the two heads of the hamstring with concurrent activation of the quadriceps could produce hip extension - a minimum requirement of four channels. Hip abduction could be provided by one channel of stimulation of the gluteus medius. Further, one channel was assigned to dorsi-flexion which can be achieved by simultaneous balanced stimulation of the tibialis anterior and peroneus longus. For balance during standing and push-off during walking, a channel was assigned to the soleus muscle. The remaining four channels were reserved for stimulation of abdominal muscles. In cases where specific functions can be achieved with fewer electrodes than assigned channels, multiple electrodes can be used in other muscles when needed.

The individualized stimulation pattern was specified to be stored in the Erasable Programable Read Only Memory (EPROM) of the stimulator in the form of look-up tables. The stimulation pattern includes pulse width values for each of the 32-channels. The patient can proceed through the stimulation pattern by controlling a two position momentary rocker switch. The first position indicates the readiness of the patient and the second position initiates a pre-programmed movement. A liquid crystal display was included to inform the patient of the next function. This is a particularly useful feature when the patient, if interrupted, forgets which stimulation function will occur next. This feature is in the form of a four character code including STND, RT ?, R GO, LF ?, and L GO, referred to as the stand, right-ready, right-go, left-ready and left-go states respectively. On power-on the stimulator automatically assumes the STND phase which is activated by pressing the second position of the momentary rocker switch. During the STND phase the stimulator sends a pre-programmed pattern of stimulation to muscles involved in standing up. These may include knee extensors, ankle plantar flexors and hip extensors. The next state automatically assumed by the processor is the right-ready state. At this point the patient can either go through the right-go state which will provide him with the left stance and right swing or he can select left-ready state and proceed through the right stance and left swing. Depressing the ready switch longer than 0.5 seconds causes the stimulator to alternate between the right-ready and left-ready states without proceeding through the stimulation pattern. The change from one state to the next occurs at a 0.5-second interval allowing the patient time to recognize and select the desired state. This firmware feature gives the patient optimal control over selection of leg motion.

The personalized stimulation patterns are developed by a combination of intuition, understanding of normal walking, and previous experience with electrical stimulation of paralyzed muscles. The patterns or look-up tables of pulse width values are generated on a DEC MINC-11/23 laboratory computer system. This system is also used to program the patterns into the EPROM used by the portable stimulator.

The stimulator was built so that it can be attached to the patient's belt. It weighs 450gm and the external dimensions are 4.5x12.5x10.5cm. A flat cable is used to provide connections to the percutaneous electrodes which are soldered to the miniature connectors. The connectors are held in place by a nonallergic tape. Thus, donning of the device is simple and it can be accomplished in a few minutes. The control and power switches can either be held in the hand or attached to the walker or a crutch.

RESULTS AND DISCUSSION

The microprocessor-controlled stimulator was used with percutaneous intramuscular electrodes by five paraplegic patients with complete lesions between T4 and T11, enabling all to stand and walk using parallel bars. Three of the patients were able to walk up to 15m with the aid of a walker for balance.

Continuing use of the stimulator reduced fatigue and improved muscle strength and the quality of walking. Although the patients have no direct information or feedback to aid in their walking, there is visual and indirect feedback. The patients learn to interpret sensations transmitted through the skeletal structure and musculature. In this manner they are able to sense foot placement and body position, improving their posture and gait.

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DIGITAL PULSE-TRAIN CLOSED-LOOP CONTROL OF MUSCLE

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ABSTRACT - A digital controller is being developed that simultaneously modulates both pulse width and interpulse interval to obtain closed-loop control of muscle outputs. We are currently evaluating this system in animal experiments.

RÉSUMÉ - On met au point un contrôleur numérique qui module simultanément la largeur de l'impulsion et l'intervalle entre les impulsions de façon à contrôler en circuit fermé les réactions du muscle. On expérimente actuellement ce système sur des animaux.

Digital closed-loop controllers which modulate pulse width have been designed and tested in cat soleus and plantaris, and found to perform well under isometric conditions [1]. These results are being extended in the design of controllers which simultaneously modulate both pulse-width and interpulse interval. We anticipate that this will result in improved controller reaction time (characteristic of IPI controllers) at low rates of muscle fatigue (characteristic of PW controllers at lower frequencies). In addition, we anticipate that the PW + IPI controller will have the good robustness properties of the PW-only controller [1], as well as some capability to adapt to changes in muscle length.

As in [1] and [2] the stimulated muscle is treated as a discrete time system rather than as a continuous system. This offers several advantages over continuous-time analysis. The nature of stimulation is that very short pulses are used to elicit twitch contractions of a group of muscle fibers. In between stimulus pulses, no control is exerted over the muscle force. The stimulator behaves as a nearly ideal sampler, varying the area of the stimulus pulses to modulate the degree of recruitment. The electrical stimulus is a train of biphasic, capacitively-coupled, cathodic-first current pulses. The electrical inputs are pulses of varying area (varying pulse width at a fixed amplitude). The pulse widths are much smaller than the time interval between pulses. Consequently, the input to the muscle can be approximated as an impulse train.

In Figure 1, we illustrate the implementation of a constant-IPI, digital pulse-width controller in the forward loop of a control configuration that is designed to regulate muscle contractive force. The output of the controller is a sequence of pulses of varying area; one pulse is produced at the start of each sampling interval. The command signal, error signal, controller output, and muscle force are sequences of values (at each sample time) having z-transforms C(z), E(z), A(z), and F(z), respectively.

This controller design was tested in cat soleus and plantaris, using the procedure described in [2]. Our analysis was based on step and ramp responses under isometric conditions, and the response of the muscle controller to length changes. The goal of these experiments was to show that the controller does in fact regulate muscle contractive force with the desired qualitative characteristics. Experimental results indicate that a very simple discrete-time pulse-width controller yields good regulation of muscle force in a feedback configuration. The controller appears to be sufficiently robust to allow for insensitivity to the model errors which accompany our choice of a simple linear discrete-time muscle model with experimentally-determined memoryless nonlinear recruitment gain.

This constant-IPI controller is the basis of a combined PW + IPI controller. The basic idea is as follows: we allow the controller to generate pulses at interpulse intervals that are integer multiples of a smallest allowable IPI, denoted by T, (typically around 10 ms). At each time interval, the controller decides whether or not to generate a pulse, thus effecting IPI modulation. This decision is made on the basis of the output of the PW-only controller (operating at the fastest time scale) at each time step, based upon the size of the current deviation between desired and measured muscle outputs (force and/or length) and on a threshold (of pulse-width). Generation of the pulse is based upon whether pulses were generated during the last few time intervals and upon the relative penalties (prespecified) on muscle fatigue (i.e., control use) and performance errors. The restriction of IPI size to a finite set of values allows the use of our existing (and tested) PW controllers. The threshold is a function of past inputs and errors. It is parameterized by a control penalty and trajectory error penalty that is "tuned" experimentally to obtain satisfactory system performance.

The basic controller configuration is shown in Figure 2. The fast-time scale pulse-width controller D(z) produces a tentative muscle input, b(k). This signal is either sent or not, based upon the decision of the IPI controller. The IPI controller makes its decision based upon past and current values of the error, e(k), and the actual muscle inputs, a(k).

The structure of the IPI controller is shown in Figure 3. A weighted average of past errors, Q_E, is compared to a weighted average of past inputs, Q_A, where $0 < \lambda_E < 1$, $0 < \lambda_A < 1$. Here P_E is a penalty on errors and P_A is a penalty on inputs. If $Q_E \geq Q_A$, then the tentative muscle input is sent; if $Q_E < Q_A$, then no pulse is sent at this time. In this way, interpulse-interval is modulated (as multiples of T). The quantities P_A and P_E can be adjusted to tune the controller; increasing P_E makes the controller more responsive to errors, e(k), and increases the average input frequency. Increasing P_A makes the controller less likely to increase the input frequency.

Good values of λ_A, λ_E, P_A, P_E must be determined experimentally. This controller design is being thoroughly evaluated in cat plantaris and soleus.

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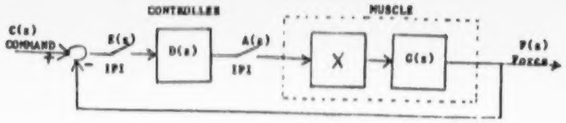

C(s)
COMMAND
+
-
E(s)
IPI
CONTROLLER
D(s)
A(s)
IPI
MUSCLE
X
G(s)
F(s)
Force

Figure 1

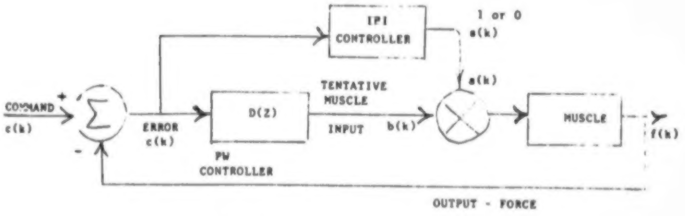
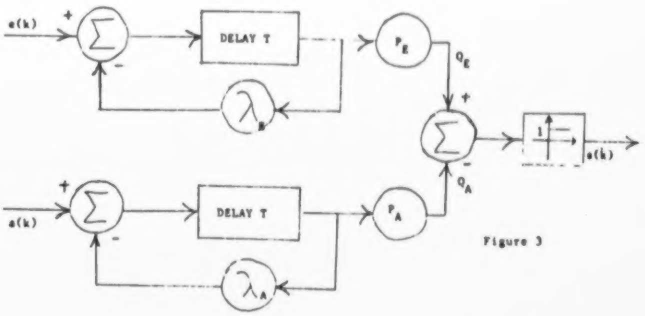

IPI CONTROLLER
1 or 0
a(k)
COMMAND
c(k)
+
-
ERROR
e(k)
D(Z)
PW CONTROLLER
TENTATIVE MUSCLE INPUT
b(k)
a(k)
MUSCLE
f(k)
OUTPUT - FORCE

Figure 2


e(k)
+
-
DELAY T
λ_E
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Q_E
+
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a(k)
a(k)
+
-
DELAY T
P_A
λ_A

Figure 3

OROFACIAL MUSCULATURE FATIGUE IN MYASTHENIA GRAVIS

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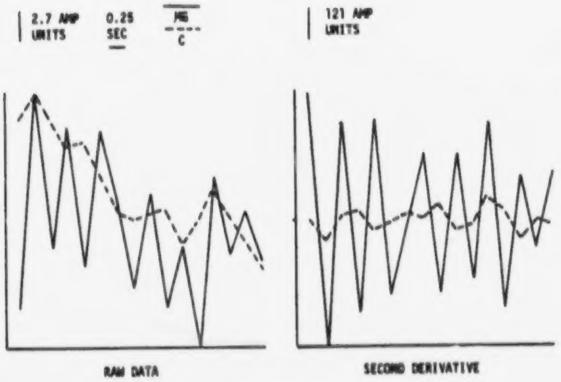
ABSTRACT - Three orofacial muscular systems were fatigued in myasthenia gravis and control subjects using maximum isometric force procedures. A large amplitude 2 Hz tremor component was observed in the myasthenia gravis force output.

RÉSUMÉ - On a induit la fatigue de trois systèmes de muscles orofaciaux chez des sujets témoins en utilisant des méthodes de contraction isométrique maximale. On a constaté un élément de tremblement de grande amplitude de 2 Hz dans la force produite au cours de la myasthénie grave.

The fatigue characteristics of the orbicularis oris (OO), genioglossus (GG), and anterior belly of the digastricus (ABD) were examined in myasthenia gravis (MG) and control subjects. These muscular systems (prominently affected in MG) were fatigued using maximum isometric force procedures. For comparative purposes, the adductor pollicis (AP) was also assessed.

Eight MG and eight control subjects participated in the study. The MG subjects were tested in an unmedicated state. Subjects were matched for age and sex. Sixty seconds of whole muscle maximum isometric force output were measured for each muscle via a force transducer. All force records were relatively scaled with respect to initial maximum force and zero applied force. Data readings were obtained at 250 ms increments.

The most prominent difference in the control vs MG fatique was the presence of a large amplitude approximately 1.5-2 Hz component in the force output of the MG subjects (Figure 1). Conversely, the matched control subjects generally exhibited smoother force output records, wherein any overriding components tended to be random and much lower in amplitude. Thus four dependent variables were chosen for detailed analysis: the integral of the raw data function and three Fourier measurements representing the highest amplitude frequency components in the Fourier analyses of the raw data function, the first derivative function, and the second derivative function (Figure 2).



RAW DATA

SECOND DERIVATIVE

FIGURE 1 ORBICULARIS ORIS

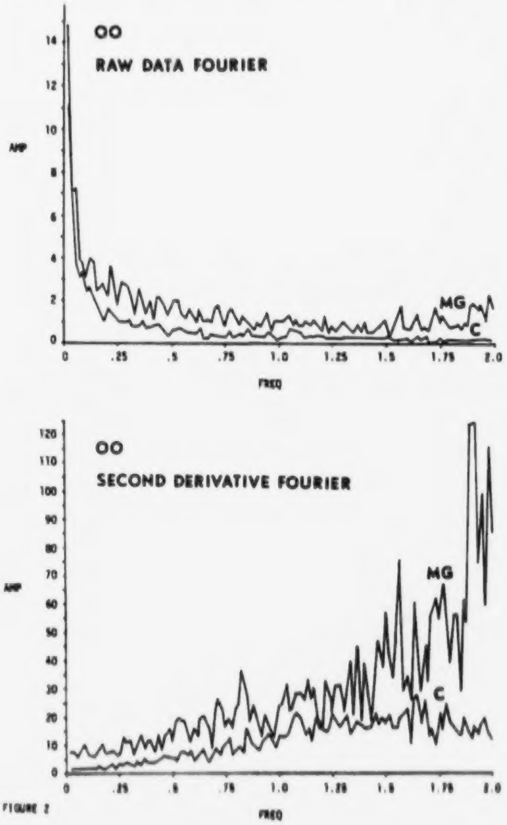


FIGURE 2

The four measures and the four muscles were examined as a function of diagnostic classification (MG vs control). Multivariate analysis of variance, multivariate regression, stepwise discriminant function analysis, multiple analysis of covariance, and simple analyses of variance and covariance were used to establish the independent effects of each variable.

The most sensitive measures differentiating the MG and control isometric force output were the second derivative Fourier measurement, followed by the first derivative Fourier measurement, the integral of the raw data, and the raw data Fourier measurement. The success of the derivative Fourier transforms lies in the sensitivity thereof high frequency components (here defined by equipment resoultion to 2 Hz) in the force output. The differences on the raw data interrgral reveal the expected greater and more rapid standardized fatigue functions for the MG subjects.

The most discriminating musculature tested was the OO, followed closely by the GG, and then by the ABD. Fewer significant differences were expected and found on the AP as the hand muscles are less likely to be prominently affected in MG. The large discriminating power of the OO and GG parallels the consistency with which these muscles tend to be the earliest and most severely affected musculature in MG.

Multiple regressions documented no effect of age or years post diagnosis on any of the dependent variables. A subjectively noticed severity effect was, however, noted.

The large amplitude 1.5-2 Hz tremor component in the isometric force output of the MG subjects is posited to be a pathological form of normal (8 Hz) physiological tremor. Normal physiological tremor is generated by single or multiple motor units discharging at an approximately 8 Hz motor unit recruitment firing rate in response to an 8 Hz neural input. Thus, given an accepted 80% reduction in the number of active ACh receptors in the affected musculature and the reduced frequency and amplitude of the miniature end plate potentials, end plate potentials, and muscle action potential, then an 8 Hz neural input is most likely to yield an approximately 2 Hz motor unit response in the MG subjects. The large amplitude of the MG tremor is most plausibly explained by the low pass response (cutoff frequency, approximately 10 Hz) of the muscular system. While the 2 Hz MG tremor is large in amplitude compared to the low amplitude 8 Hz normal physiological tremor, the MG 2 Hz amplitude is smaller in amplitude than that which would be artificially induced by 2 Hz neural stimulation in control subjects.

The recommendations resultant from this study include more sophisticated procedures (e.g., digital data sampling and Fourier transforms to 40 Hz). Additionally, the differential effects of drug regimens, menopausal status, "good" vs "bad" days, etc. should be eximined. It is anticipated that the primary differences to be found herein would involve the amplitude rather than the frequency of the tremor components. Longitudinal studies might be undertaken (1) to study the progression of MG to other muscular systems and (2) to determine the existence of subclassifications of MG. Additionally, spectral analysis of isometric force output should be extended to other neuromuscular pathologies (especially the myasthenic syndrome, a true ACh deficiency mimicking, in many ways, MG). Finally, the use of such procedures as monitoring and counseling tools might also be recommended for large diagnostic institutions.

RESTRENGTHENING PARALYZED MUSCLE IN SPINAL CORD INJURED PATIENTS BY ELECTRICAL STIMULATION: PREDICTING RESTRENGTHENING OUTCOME AND MEASURING THERAPEUTIC BENEFITS

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ABSTRACT - We are beginning a study to determine if we can predict the successful restrengthening by electrical stimulation of lower limb muscles paralyzed by spinal cord injury. Such a prediction is to be based on an initial assessment of a patient's neuromuscular system and case history. We are also measuring the therapeutic benefits that might be brought about by such restrengthening.

RÉSUMÉ - Nous commençons une étude pour déterminer si l'on peut prévoir les chances de succès du renforcement par stimulation électrique des muscles des membres inférieurs paralysés à la suite d'une lésion de la moëlle épinière. Cette prédiction sera fondée sur l'évaluation initiale du système neuro-musculaire du malade et sur l'histoire de sa maladie. Nous mesurons également les bienfaits thérapeutiques que peut amener ce renforcement.

There has been tantalizing evidence from various research laboratories that electrical stimulation of muscle might be a valuable tool for restoration of functions lost following spinal cord injury. Yet, important questions remain. Can all paralyzed, but innervated muscles be restrengthened to a level necessary to carry out a particular function with a minimum of fatigue? What factors might predict successful restrengthening? What therapeutic benefits might arise to an individual as a result of such restrengthening?

Electrical stimulation of leg muscles: We are beginning a study aimed at answering these three questions using individuals with paraplegia and quadriplegia who are patients of the Spinal Cord Injury Service of the United States Government's Veterans Administration Hospital at Hines, IL. Such a predominantly male population provides a diverse mix in terms of level and completeness of injury, actual age and years post injury, height and weight, extent of cardiovascular, renal, urinary, skeletal, neuromuscular, peripheral vascular, cutaneous and psychological complications brought on as a result of spinal injury. We attempt to restrengthen the extensor muscles (quadriceps) of the knee by electrical stimulation applied to the skin overlying these muscles via large surface electrodes, following techniques originally developed by groups in Yugoslavia and California. Stimulation is applied in cyclic fashion (5 sec on, 5 off) to each leg using a 20 Hz monophasic stimulus train in twice-daily 15 minute sessions. One criterion of successful restrengthening requires that electrical stimulation be able to move each leg to within 10 degrees of full extention for at least 20 minutes.

Targeted Population: We use a patient's history to screen for prospective candidates who would not be put at a known risk by lower-limb muscle stimulation. Absolute contraindications include lower motor neuron paralysis of the muscle to be stimulated, severe peripheral vascular or cardiovascular compromise, decubiti in areas affected by stimulation, and severe psychosocial problems.

Factors Predicting Restrengthening: Other factors in a patient's history and clinical workup should be important predictors of restrengthening success or failure. We expect that success will be directly correlated with shorter time since injury, the completeness of sensory (but not necessarily motor) involvement, and the presence of moderate spasticity and clonus, as well as other factors. The level of the lesion (as long as above L1) should not be a major factor for predicting lower limb restrengthening.

We are deriving measures other than those typically assessed clinically that should also have a high degree of predictive power. These other measures include 1). an assessment via computer aided tomography of the cross-sectional area of the quadriceps in relation to limb girth, body height, body weight, and femur cross-sectional area, 2). A quantification of muscle spasticity, and 3). a measure of the force and fatigue properties of electrically stimulated muscle during isotonic and isometric exercise.

Therapeutic Benefits: It is axiomatic that simple ranging of a paralyzed limb by an individual with spinal cord injury, or by his or her therapist or care giver, provides important short-term, and occasionally long-term, therapeutic benefits to that individual. Such benefits might include preservation of range of motion, reduction or relief of spacticity or clonus, reduction of edema and deep vein thrombi formation, improvement of peripheral circulation, and a slowing of muscle or joint ossification. Similarly, these benefits might also accrue to an individual whose limbs are being moved by surface electrical stimulation. And, in fact, certain of these benefits have been noted as side benefits of muscle stimulation.

In conjunction with physiatrists, therapists, and other health professionals, we are determining to what extent electrical stimulation influences these factors both in the short term (during stimulation), and long term (after at least a month of stimulation). Other factors, such as psychological well-being and urodynamic function as also being monitored for changes.

Example of Measures: While this study is still in its early stages, we will be illustrating some of our predictive and therapeutic measures with the examples taken from individuals in our program.

Results to Date: Preliminary studies on determining predictive factors have begun with three patients of the Hines VA Spinal Cord Injury Service: a healthy C7 (complete) quadriplegic on medication to control spasticity, a T9/T10 (complete) paraplegic also on antispasticity medication, and a T11 (incomplete sensory and motor) paraplegic with possible lower motor neuron involvement on one side. These patients have given informed consent to our research protocol. CAT scans have been taken of the upper legs on all three patients. EMG analysis has been performed for the patient with the C7 lesion; the other two are being scheduled. Initial response to electrical stimulation of the quadriceps has been measured in two of these patients. As might be expected, preliminary results suggest a possible correlation between residual muscle mass (as determined by CAT scan) and initial response to electrical stimulation (see Figure 1). Whether this relationship holds during and after restrengthening, or whether other variables could predict success, is currently being studied on a limited scale.

Figure 1: The tomographic images of the legs have so far yielded valuable clues as to why electrical stimulation was effective in producing limb movement in some of our subjects but not in others. It is apparent in this figure that much more quadriceps muscle mass remains on the left leg than on the right leg of this patient (Scan taken 213 mm above the patella). The right vastus medialis is almost entirely atrophied, and fatty inclusions are seen throughout the remainder of the right quadriceps. This patient has some voluntary movement on the left, none on the right. Since this patient had an incomplete sensory and motor lesion, he could only tolerate about two-thirds of the maximum stimulus intensity of 100 v. Nevertheless, this voltage was sufficient to produce slight movement in the left but not the right leg. While this patient was recommended as a good candidate and was very cooperative, muscle restrenghtening by electrical stimulation was contraindicated because of the presence of lower motor neuron involvement and an almost intact sensation.

CHARACTERIZATION AND LINEARIZATION OF OPEN LOOP HAND CONTROL USING FUNCTIONAL NEUROMUSCULAR STIMULATION

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ABSTRACT - Studies are being conducted to characterize and linearize the relationship between command input and the resulting hand position and force, where the command input determines the stimulation parameters applied to the muscles in an open loop configuration.

RÉSUMÉ - On effectue des études en vue de caractériser et de linéariser la relation entre la commande donnée et la position et la force résultantes de la main, lorsque la commande donnée détermine les paramètres de stimulation appliqués aux muscles dans une configuration en boucle fermée.

INTRODUCTION:

Functional neuromuscular stimulation (FNS) of paralyzed muscle can provide functional grasp in the quadriplegic [1]. The systems currently in use are open-loop systems(i.e. no internal feedback of performance parameters). Coordination algorithms have been previously developed in an emperical manner to simulataneously control the stimulation paramaters to several muscles with a single input command [3]. The purpose of this study was to characterize the input-output relationship between stimulation parameters and thumb force and position, and utilize this information to design coordination algorithms which will provide a linear relationship between command input and thumb force or position. The degree of linearity in this input-output response will be a determining factor in how precisely a subject will be able to control his hand.

MATERIALS AND METHODS:

Apparatus. The forearm and hand muscles of quadriplegic subjects have previously been implanted with percutaneous wire electrodes for electrical stimulation of the thumb and finger musculature. The subject's forearm was held rigidly in a monitoring apparatus which has transducers for measurement of thumb force and position[2]. The force transducer was a load cell placed against the pulp of the thumb. The position transducers were low mass and friction two degree of freedom joysticks which were attached to the frame such that they lie in the same plane, but orthogonal to each other. Rods were fixed to the transducer at one end and attach to the thumb tip with low friction ball and sockets at the other end. This arrangement enabled us to specify the postion of the thumb tip in three dimensions.

Experimental Procedure A laboratory computer system(DEC PDP 11/23) was used to coordinate the control of stimulation parameters applied to the muscles. This coordination algorithm consisted of tables of pulse width and interpulse interval values which generate the finger and thumb movement and force in response to the input command [4]. In these experiments, the computer generated step input command changes and simultaneously sampled the ouput response at 100 Hz. Three different types of experiments have been performed. The initial experiment consisted of characterization of the pulse width versus force relationship at a single muscle length of a thumb flexor. This information was used to develop a command versus pulse width algorithm to compensate for nonlinearities in the recruitment curve. Using this algorithm, the new command input versus force output relationship was characterized to determine the degree of linearity. The objective was to have the full command range linearly control force or position. Experiments were then conducted to determine the effect of varying the muscle length on the command versus force relationship. The final set of experiments were conducted to characterize the relationship between pulse width and thumb position during step changes in the input command. Thumb position was measured during application of 2 second stimulus trains at an initial command level, immediately followed by another 2 second stimulus train at a final command level. This procedure was designed to test whether the final position obtained was a function of the final command input alone or both the initial and final command input.

RESULTS

The force experiments were conducted with two subjects using a single thumb flexor muscle. It was found that a command versus pulse width relationship could be developed which would provide a linear command versus force relationship. Figure 1 shows the recruitment curve obtained with one of the subjects. The curve is similar to that reported previously [1]. This nonlinear relationship was then inverted to create the command versus pulse width relationship, where the percent of normalized force at a given pulse width corresponds to the command percent at that pulse width. The new command versus force relationship was then characterized and compared to the original command versus force relationship (Figure 1). The new curve is quite close to the desired 45 degree line.

Experiments were conducted with two subjects to determine the recruitment curve at three different muscle lengths. For each length the force output was normalized to the force at the maximum pulse width. In both subjects, when comparing the normalized recruitment curves at the longest and the middle muscle length, the curves are similar indicating little or no length dependent recruitment Figure 2. When comparing the normalized recruitment curves at the shortest and the middle muscle length, one subject again showed a minimal amount of length dependent recruitment (Figure 2), while the other subject showed a significant amount. The reason for this difference between subjects is not known, but is presently being investigated.

Experiments were conducted with two subjects to characterize the thumb position as a function of pulse width. The thumb extensor alone was evaluated first. The results with one subject are shown in Figure 3. As shown in the figure the final position obtained was a function of both the initial and final command inputs. The bars indicate the range of the final position at each final command for a series of different initial command levels. Additionally, the input-output response was nonlinear and did not provide control of position over the full range of motion. The effect of cocontraction of the thumb flexor on these characteristics is presently being investigated.

In the future, we plan to repeat the force characterization experiments with additional subjects and continue the investigation of cocontraction for the linearization of position control.

ACKNOWLEDGEMENTS

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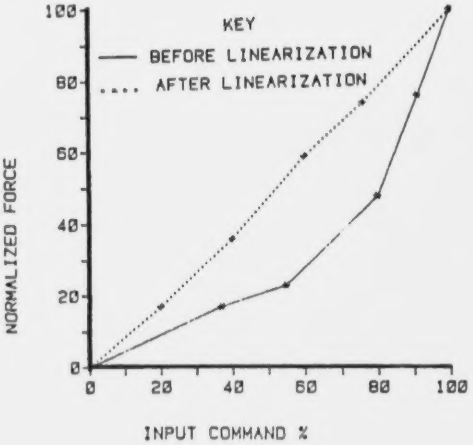

FIGURE 1

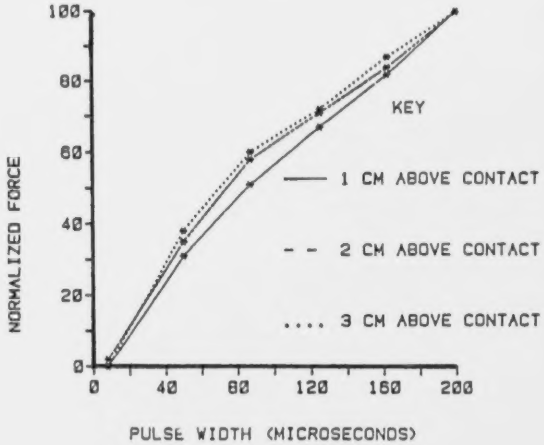

FIGURE 2

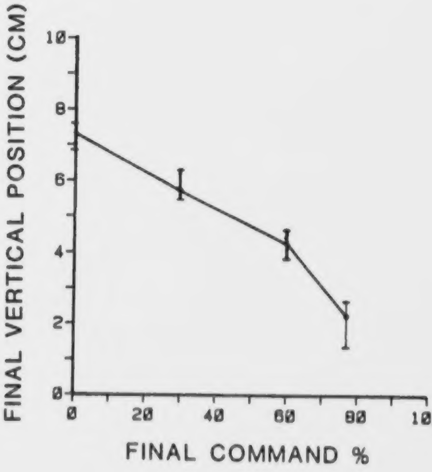

FIGURE 3

DEVELOPMENT OF A CLOSED LOOP CONTROL SYSTEM FOR HAND FUNCTION RESTORATION USING FUNCTIONAL ELECTRICAL STIMULATION

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ABSTRACT - We are developing a digital closed loop control system for the regulation of antagonist muscles in the hand. Muscle stiffness is to be regulated by modulation of muscle recruitment and temporal summation. We are currently evaluating the separate components of the system under laboratory conditions.

RÉSUMÉ - Nous mettons présentement au point un système de commande numérique en boucle fermée le contrôle de muscles antagonistes de la main. La raideur musculaire sera contrôlée par modulation du recrutement musculaire et sommation temporelle. Nous évaluons présentement en laboratoire les composantes distinctes du système.

Functional electrical stimulation of skeletal muscles of the paralyzed hand offers a means of neuroprosthetic replacement of lost hand functions. By adding closed loop control to the open loop systems, we can improve repeatability by automatic compensation for time varying muscle properties (such as fatigue). Recently, digital closed loop control systems have been successfully designed and evaluated for muscle force regulation in cats [1]. We are presently evaluating these controllers, along with other controllers [2] under clinical laboratory conditions for their eventual incorporation into orthoses.

SYSTEM DESCRIPTION

We are developing and evaluating the microcomputer based system shown in Figure 1. This is a joint-stiffness control system to regulate a pair of antagonist muscles in the hand. With this control system, muscle force and joint position are coupled as follows: $F = K\ (C-P)$, where K is a user-defined target stiffness value. This stiffness control scheme is discussed in more detail below.

Muscle Activation

Pulse width modulation, at fixed current amplitude, is used to control recruitment in the low to moderate force range, whereas interpulse interval (IPI) modulation controls the high force range by temporal summation. (The electrical stimulus is a train of biphasic, capacitively-coupled, cathodic-first current pulses). During pulse width modulation, IPI is fixed at a value resulting in 10% ripple in muscle force. In this manner, functional contraction is achieved and unnecessary fatigue is minimized. For futher increases in muscle force, IPI is reduced with pulse width fixed at its greatest value. Each muscle is controlled similarly, but in making the transition between flexion and extension both muscles are activated (co-contraction) to increase joint stiffness.

Pulse Width Controller

The pulse width controller for force modulation [1] is based on a sampled data system model of stimulated muscle [3]. The controller is a single pole, single zero compensator in the Z domain, $D(z) = d(z-n)/(z-1)$, implemented as a difference equation. The pole at $z=1$ results in zero steady-state error. Successful force regulation of cat soleus and plantaris muscle using this controller is demonstrated [1]. Modifications of this controller may be necessary to satisfy response criteria under conditions of changing muscle lengths.

Interpulse Interval Controller

The steady-state controller relation is $\mathrm{IPI} = \mathrm{IPImax} - (1/\mathrm{slope})^{*}\ (\mathrm{error})$, where IPImax is the IPI used during pulse width modulation. The value of slope determines the controller gain. Successful force and position regulation have been demonstrated using this controller in cat soleus muscle [2] and with human finger muscles [unpublished observations].

Stiffness Controller

A combination of position and force feedback is needed for adequate system performance under the full range of loads that are likely to be encountered [2]. In addition, the combination can provide regulation of stiffness to approximate the moderate values observed in normal hand muscles under reflex control [4]. Position feedback alone could provide good regulation with high compliance loads, but would not be adequate for high stiffness loads, since the gain of the position feedback loop would be too low. For similar reasons, force feedback alone could not regulate performance in the absence of a load (high compliance). The stiffness controller is presently being studied separately, but is included in this abstract for completeness.

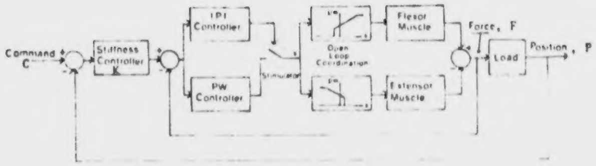

Figure 1

EVALUATION OF CONTROLLER PERFORMANCE

Various commands are being used to evaluate the system's performance: steps; ramps; and truncated ramps. Controller performance is being evaluated quantitatively by measuring rise time, percent overshoot, settling time, and steady state error for step inputs. Since step commands are unlikely to be encountered clinically, ramp responses and truncated ramp responses are also being evaluated.

We are developing the system by first evaluating the force regulation performance of our existing pulse width controller. The controller is implemented on a DEC PDP-11/23 laboratory microcomputer. Force is measured with existing laboratory transducers that require the forearm and hand of the subject to be fixed in space.

An example of a step response from a preliminary study is shown in Figure 2. The control system was set up to regulate the force of flexion in the long finger by intramuscular stimulation of the flexor digitorum superficialis. The patient had spinal cord injury at the C5/C6 level with no voluntary control of the stimulated muscle. The pulse width controller transfer function was D(z)= 0.01 (z-0.6)/(z-1). IPI was constant at 55 msecs and a maximum pulse width of 37.4 usec was necessary to achieve the command of 0.2 Newtons. Time to peak force was 2.4 seconds; percent overshoot was 16%; settling time was 4.3 seconds; and steady-state error approached zero.

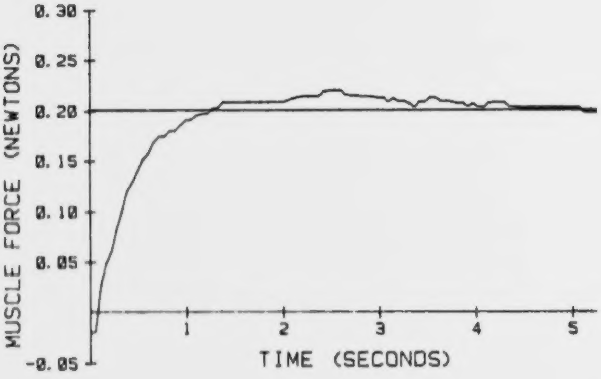

Figure 2

ACKNOWLEDGEMENTS

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THE CONTROL OF FES ENABLED GAIT IN SPINAL CORD INJURED PATIENTS

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ABSTRACT - This article reports the use of electrical stimulation to provide paraplegic patients with complete lesions the ability to walk with a reciprocal gait. The control over simple gait pattern is provided by hand switches and potentiometers built into the handles of the crutches.

RÉSUMÉ - Le présent article traite de l'utilisation d'une stimulation électrique pour permettre aux paraplégiques ayant des lésions complètes de marcher grâce à une méthode de démarche réciproque. Le contrôle sur la démarche simple est assuré par des interrupteurs et des potentiomètres intégrés aux poignées des béquilles.

After the spinal cord injury electrical stimulation muscle strengthening, erect standing and simple biped gait training can be performed (1,2). While developing our own methodology we recognized that the control possibilities, safety and cosmetic issues are appearing as key problems among other problems like long lasting surface electrodes, implantation technology etc. Here we would like to discuss the control possibilities. There are numerous control modes possible for FES orthoses like shoe insole control signal pick-ups, hand switches, position, force or pressure control signals obtained from sensors placed at different body sites and EMG signals. Because of simplicity switch control was mostly used so far. Our more than ten years experience shows that shoe insole switch on the heel or metatarsals of stroke and other ambulatory patients and hand switch control in complete SCI patients seem to be practical yet limited control. switch control performed so far is very dependable and good but in essence we are not satisfied with it. Here we are reporting about our approach of developing a simple switch control usable in FES enabled locomotion activities in SCI patients. The standing-up and sitting-down control is performed by a single switch which is a part of the stimulator itself. Considering the reciprocal gait the control must enable left and right side swing and stance phase control. The simplest way is to use a left and right side control switch. Once a patient learns to use for stability and safety assistance the roller walker (1) and is able to control the gait by himself, it was recognized that the thumb is the only free and the most natural activator for the control switch and other necessary adjustments. This has been also proven appropriate for lately achieved crutch walking (2). In our current systems surface electrodes are used, requiring stimulation amplitude readjustments for allowing prolonged locomotion activities. It seems logical that with any sort of electrodes and stimulation modes some tuning and readjustments will be required in critical and important situations. For the patient's comfort and safety in our 4-channel FES enabled reciprocal gait the knee extensors (m.quadriceps)stimulation amplitude and the flexion reflex stimulation amplitude must be controlled. Therefore, two potentiometers for amplitude adjustments are mounted on the crutch handle and are accessible by the thumb for setting (Figure 1). Such a design was demanded by the patients and resulted in a distributed electrical stimulator as shown schematically in Fig.2.

Because independent and safe standing-up and/or sitting down only by crutch

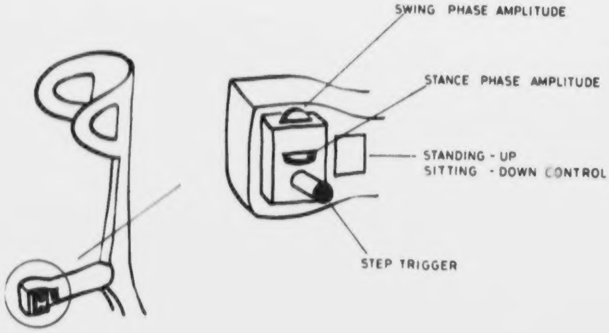

Figure 1

assistance is in many patients not achievable other support is required (a solid support at least for one hand). The standing-up control should be therefore provided also at the stimulator site featuring a delay, allowing adequate time for preparing firm grip and trunk positioning before the stimulation starts (3). Our crutch walking patient complained because of the stimulator size, which was mainly determined by bulky batteries. Therefore, the batteries were attached separately and the stimulator maximally miniaturized.Also because of cosmesis and weight distribution, the described design was proven to be reasonable. At present cables and connector connections are made among the parts of the stimulator. We would prefer at least to have RF,ultrasound or infra-red connections to the crutches containing the control transducers. All the ambulation events so far are controlled by the patient himself and there is no preprogrammed activities. There is only simple logic circuit in the stimulator for rejecting false and forbidden control signals thus improving the safety. It seems that at the present a microprocessor, if used in the stimulator design, can improve the internal organization, functioning and logistics, but can not much improve the control provided in the patient by means of the control switches. On the contrary, it seems that microprocessor based multichannel stimulator will in the former case to some extent complicate the hardware of amplitude adjustments.

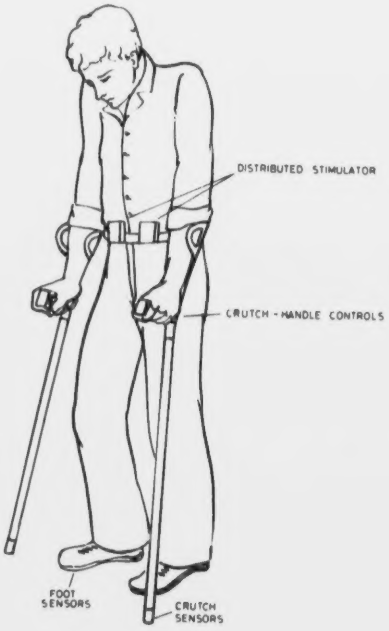

Figure 2

The reasoning is totally different if sensors providing artificial proprioception of the actual patient performance are added. If external proprioception is introduced, the microprocessor based controller and stimulator will incorporate some criteria and rules determining the state of the patient's extremities. Logic control signals for the FES channels will be computed by the microprocessor in open-loop principle. In this way the stimulator design can optimally utilize the knowledge we possess and advantages of the inexpensive microprocessor computing power improving the overall patient-stimulator system performance. Important to mention are also the walking speed and cadence dependent changing of important parameters like stimulation channels timing and stimulation amplitude resulting in adaptive control, improved safety and prevention of hazardous situations. If latter occurs logical control will as an"artificial reflex" smoothly interact and falling, perturbations caused by external forces and/or slipping or suddenly changed terrain configuration will be safely executed.

To conclude the discussion of control and stimulator design for SCI patients enabling them reciprocal gait and other locomotion activities it seems that a distributed stimulator design (even for implanted versions) with separated control and sensory perception sites and power supply is justifiable and necessary. It is also important to recognize that microprocessor based stimulators and/or control can improve the performance and function only after additional artificial sensory perception channels are used. Only in the latter case adaptive control and overall system performance optimization can be effectivelly performed. The distributed stimulator (Fig. 2) and distributed control together with artificial proprioception seem to represent the most challenging approach at the present.

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QUANTIFICATION OF CHANGES IN PASSIVE RESISTANCE AND GAIT INDUCED BY ELECTRICAL SPINAL CORD STIMULATION

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ABSTRACT - The effects of continuous electrical spinal cord stimulation on passive resistance in ankle and knee joint muscles were evaluated. Reduction of tonic stretch reflex activity resulted in improvement of voluntary control and gait.

RÉSUMÉ - Les effets de la stimulation électrique de la moelle épinière, sur la résistance passive des muscles des articulations du genou et du tarse ont été évalué. La diminution de l'activitée du reflexe tonique de tension, a résultée dans l'amélioration du contrôle voulu et de la marche.

Since Cook's and Weinstein's (1) original observation, that continuous spinal cord stimulation (SCS) improve patient's voluntary motor control and sensory appreciation, many reports dealing with the effects of this therapeutic technique have been published. SCS has been applied in patients with multiple sclerosis, but has also been used in those with spinocerebellar disorders, different types of generalized or local forms of dystonias, cerebral palsy, and incomplete spinal cord injuries. Evaluation of the beneficial effects of SCS on abnormal motor control (spasticity, impaired coordination, bladder dysfunction) has been based primarily on clinical observations. A useful list of references is given in (2).

With the aim to quantify the effects of SCS on motor control we studied five patients: 2 with multiple sclerosis (J.M. and S.T.), 2 with Friedreich's ataxia (V.S. and B.V.), and one with undetermined form of hereditary ataxia (H.J.). Chronically implanted Avery Labs systems for SCS were used. Electrodes (E355) were placed in the epidural space over the dorsal portion of the upper thoracic spinal cord segments. Monophasic pulses with a pulse width of 200 microseconds and frequency between 30 and 150 Hz were employed. Stimulation intensity was adjusted to a level close to sensory threshold (approximately 2-5 mA).

Passive resistance to muscle stretch in knee and ankle joint muscles of both extremities was measured by pendulum test (3) and by electrohydraulic measuring system (4). Functional abilities were evaluated by measuring maximal voluntary isometric contraction forces of the ankle joint muscles and by measuring following gait parameters: velocity, step length, hip, knee and ankle goniograms and basograms (5).

Recordings were made after the SCS was discontinued for at least 24 hours and during continuous electrical stimulation. Patient B.V. was unable to walk without assistance. Therefore measurements of gait parameters were not performed. In both patients with Friedreich's ataxia better voluntary control (Tab.I) and in patient V.S. faster walking (Tab.II) were observed during stimulation.

PATIENT	MAXIMAL ISOMETRIC CONTRACTION (Nm)							
	WITH STIMULATION				WITHOUT STIMULATION			
	plantar flexion		dorsal flexion		plantar flexion		dorsal flexion	
	R	L	R	L	R	L	R	L
V.S.	17.5	15.5	25.0	25.5	19.5	8.8	17.3	19.0
B.V.	8.8	12.0	7.8	7.8	7.8	9.0	6.8	4.2
H.J.	19.0	14.0	24.0	14.0	26.0	16.0	30.0	29.0
S.T.	7.4	4.6	5.4	6.1	4.8	2.8	3.6	3.9
J.M.	19.0	8.5	17.0	10.5	14.0	4.0	13.0	8.0

Table 1

Shortening reaction in flexor muscles of the lower extremity which decreased the resistance to passive movement, together with increased stretch reflex activity, was presented in patient H.J. Slower gait, shorter steps (Tab.I) and decreased strength in ankle joint muscles (Tab.II) were noticed when the stimulation was applied. Resistance to passive movements in ankle (Fig.1) and knee joint muscles (Fig.2) was decreased, while the EMG activity during shortening was increased.

Intensity of tonic and phasic stretch reflex as well as biomechanical properties determine the resistive torque due to passive movement of joints in spastic patients. Fig. 3 shows the record of sinusoidal passive movements of left ankle joint at 2 Hz (amplitude 15^o and maximal velocity 188,4^o/s) in MS patient J.M. During stimulation (continuously applied for one week) resistive torque was augmented due to increased phasic stretch reflex activity (Fig.3a). After one week without electrical stimulation phasic stretch reflex was

PATIENT	AVERAGE GATE VELOCITY (m/s)		AVERAGE LENGTH OF DOUBLE STEP (m)	
	with stimulation	without stimulation	with stimulation	without stimulation
V.S.	0.73	0.68	1.19	1.16
H.J	0.81	0.85	1.20	1.22
S.T.	0.28	0.26	0.76	0.76
J.M.	0.44	0.30	0.83	0.66

Table 2

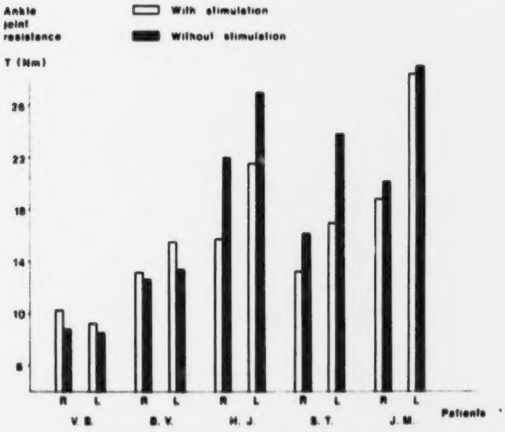

Fig.1: Ankle joint resistance with and without stimulation

slightly depressed and tonic stretch reflex activity appeared while resistive torque increased minimally (Fig. 3b). Resistive torque due to position controlled movement at other velocities, i.e. frequencies (0.1, 0.5, 1 and 1.5 Hz), did not considerably change, as well as relaxation index obtained by pendulum test. In both MS patients better voluntary control (Tab.I) and walking (Tab.II) during stimulation were achieved.

It has been already reported that the tonic stretch response was depressed by dorsal column stimulation but had no effect on the phasic stretch reflex response in triceps surae in the cat (2). Reduction of tonic activity in triceps surae in the cat with cerebellar stimulation was reported (6). Similar effects were produced by means of direct muscle stimulation on hemiplegic patients (7).

Therefore it can be concluded, that SCS reduces the tonic stretch reflex activity to different degrees. Suppresed tonic stretch reflex results in improved functional ability. In this respect the effect of SCS mimics the chronic cerebellar and peripheral electrical stimulation.

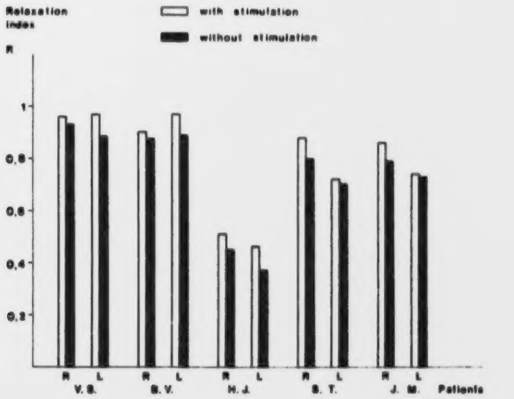

Fig.2: Relaxation index obtained by pendulum test. Level of spasticity corresponds to the difference 1-R.

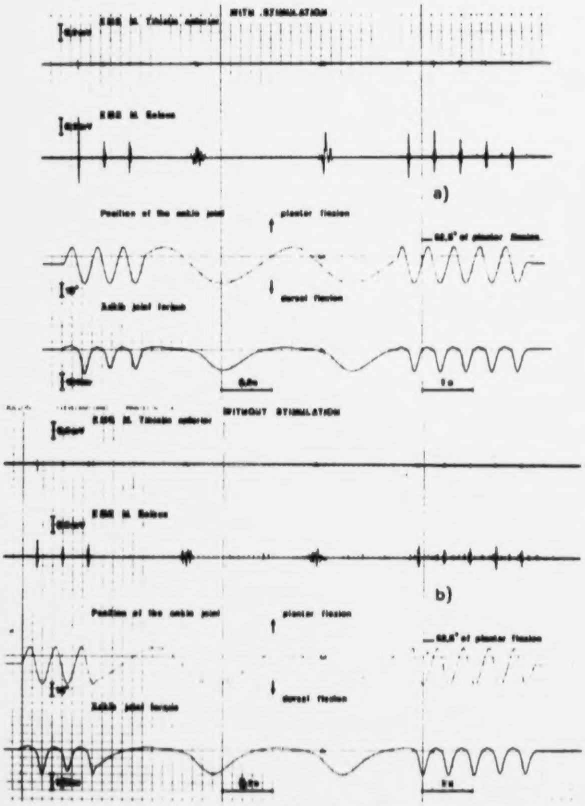

Fig.3: The tonic stretch reflex activity did not occur during the stimulation (a), while it was present when the stimulation was not applied for longer period (b).

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DYNAMIC FEEDBACK CONTROL OF ANKLE JOINT ANGLE IN SPASTIC CEREBRAL PALSY USING FUNCTIONAL ELECTROSTIMULATION

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ABSTRACT - A strategy is described for controlling joint position in children with spastic cerebral palsy during walking using functional electrical stimulation. The control system incorporates positional feedback and dynamic timing adjustments.

RÉSUMÉ - On décrit une stratégie de contrôle de la position des articulations en cours de déambulation chez les enfants atteints de paralysie cérébrale spasmatique au moyen de la stimulation électrique fonctionnelle. Le système inclut des réglages de rétroaction positionnelle et de synchronisation dynamique.

Introduction

The ability of electrostimulation to replace missing muscular activity or to suppress uncontrollable contractions during functional movements such as locomotion depends in part on the generation of signals to control stimulation. In particular, control systems should be designed so that the conscious effort needed to operate them should not be prohibitive[1,2]. Examples of such systems are: the foot-switch used to initiate stimulation of the peroneal nerve for correction of drop-foot[3]; and preprogrammed routines whereby stimulation of multiple muscle groups occurs in a specific sequence as determined by gait analysis[4]. The foot-switch can also be used to adjust duration and onset of stimulation according to step rate[5].

The need to incorporate dynamic control in FES systems has been recognized for more than a decade. A means is needed to regulate stimulation to account for changes in load and muscle length, shifting of stimulating electrodes and the resultant variability in elicited movements. Control waveforms used to regulate stimulation should be generated by the walking action itself if they are to be part of a feedback control system. Such waveforms include joint-position[6,7], electromyographic activity[8], and force[9]. Naumann and Milner[10] reported on an adaptive control system incorporating feedback from the stimulated leg in stroke patients. This paper describes an adaptation of this control concept in which prerecorded movement data are used to control movement of spastic limbs in children with cerebral palsy through electrostimulation.

Instrumentation

A 4-channel stimulator with the provision for incorporating feedback control was used. It produces 0.2 mS rectangular constant current pulses amplitude modulated by a control waveform at a frequency of 50 Hz. A level shift is used to cancel any D.C. level differences between the control and feedback inputs. This enables a 'zero' reference angle to be set between the two channels. A positive difference between the two input signals with respect to this reference level, say, results in stimulation of the foot dorsiflexors. Independent threshold settings ensure that a preset threshold stimulus appears at the output of each channel only when that channel is activated by the controller. Proportional-integral filters were incorporated into the controller to prevent oscillations of foot movements[7].

The control signal was derived from an electrogoniometer attached about the ankle joint of a normal subject and stored on a PDP11/34 computer. The sagittal plane ankle joint movement from toe-off on the ipsilateral side to toe-off on the contralateral side was isolated and adjusted to contain 200 data points. Footswitches were used to supply bilateral gait timing information.

Interactive Program

Calibration: Electrogoniometers are attached bilaterally and connected to the feedback ports of the stimulator. Each foot is set to the expected angle at toe-off and to the position of desired maximum dorsiflexion. These two positions are sampled for each side by the computer and the control waveforms adjusted so that D.C. offsets are added to them equal to the first position and their amplitudes scaled to provide signals equal to the desired maximum dorsiflexion. These waveforms are then outputted from the computer to the stimulator on demand. In between calibrations, a signal equal to toe-off ankle angle is played out. Following calibration, the outputs of the goniometers are continuously sampled and played out to the control ports of the stimulator so that no stimulation occurs. The subject then stands up in preparation for walking.

Control of gait: The computer is signalled to check for toe-off on either side. The feedback signal is played to the input control ports until the third occurrence of toe-off on each side at which time stimulation begins. At the occurrence of toe-off, the number of sampled data points in the previous ipsilateral toe-off to contralateral toe-off period is compared to the number of data points in the control signal. The control signal is then modified by dropping or repeating equally spaced data points so that it conforms in time to this period. If this is longer or shorter than the preceding period, the last value of the control signal is outputted until contralateral toe-off occurs, or stimulation on the ipsilateral side is halted respectively. Following the collection of 2000 data points per channel the feedback signals are again fed to the control ports. Thus stimulation occurs only during steady-state walking.

Results

Figures 1(a) and 1(b) depict the movement patterns and stimulus waveforms for one footstep recorded from a 12-year old child with spastic diplegia during walking without and with stimulation respectively. Note that only the peroneal nerve on the left side was stimulated. The DC-offset therefore appears only on the left stimulus control waveform.

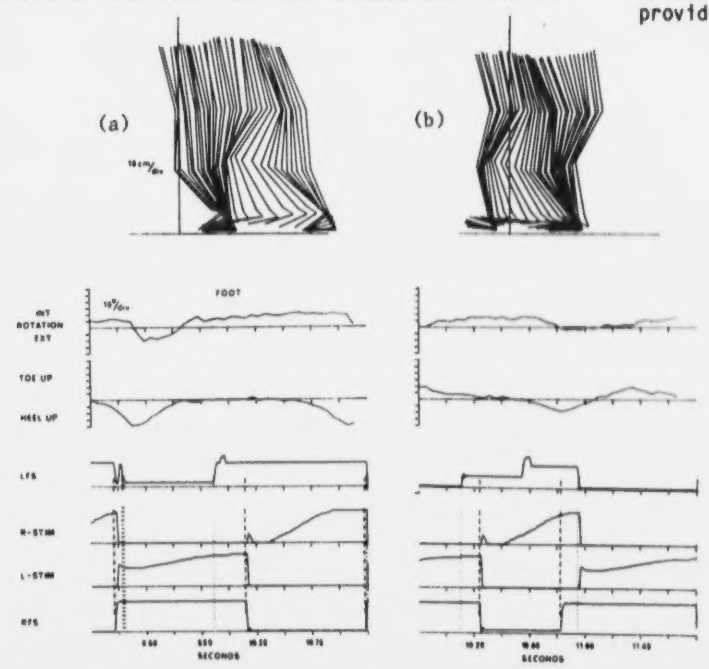

Figure 2. Representation of patterns of left-hand-side of child with cerebral palsy.
(a) Without Stimulation
(b) With feedback Stimulation

From top to bottom:

Sagittal projection of connected markers versus distance.

Rotation of foot in transverse plane versus time.

Sagittal projection of angle between foot and floor.

LFS - Left footswitch
R-STIM - Stimulus control waveform to right side (not used)
L-STIM - Stimulus control waveform to left side
RFS - Right footswitch

Without stimulation (Figure 1(a)) the child had only toe-contact except for a brief period of footflat on the left. There was a brief toe-drag on the left at the start of swing. The left foot internally rotated except during early to mid-swing when it externally rotated to about 20°. The angle between the foot and floor peaked at 40° during early swing with the foot plantarflexed. With stimulation (Figure 1(b)), a good heelstrike was achieved but the foot internally rotated by 2° during toe-off. The toe was above the level of the heel except during the push-off period and the first 14% of the swing phase. The speed of walking more than doubled with stimulation but step-length decreased by 17%.

Of concern were decreased hip and knee angles of extension with stimulation, the maximum extension at the knee and hip having decreased from 17° to 27° and 10° to 25° of flexion respectively. Sagittal plane movement of the ankle also decreased from a range of 25° to 12°, the changes in foot position with respect to the floor mainly resulting from movement of the limb as a whole. When stimulation was applied with the child seated or during open-loop control, the foot moved freely as stimulus intensity increased or decreased. A possible cause of the rigidity seen during feedback-controlled stimulation may be the result of goniometer slippage and hence the occurrence of stimulation during the single-support phase. The program is to be modified so that the feedback signal will be fed to the control port during single-support phase to prevent this occurrence.

Variations seen in gait patterns during open-loop stimulation were greatly decreased during closed-loop stimulation. Because of the observed rigidity in this case, it is not possible to attribute this decrease exclusively to the feedback provided by close-loop stimulation.

Acknowledgement

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WALKING WITH AN IMPLANTABLE STIMULATION SYSTEM FOR PARAPLEGICS

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ABSTRACT - Following several animal experimental series concerning direct nerve stimulation during the last 10 years, an implantable system for active hip- and knee-joint extension in paraplegics was constructed. In October 1982 this system was implanted in two paraplegic patients. 6 months after the operation both patients learned to walk with crutches using this system. Two more patients have been treated with this system during the last 3 months.

RÉSUMÉ - Après avoir réalisé plusieurs séries d'expériences sur la stimulation nerveuse directe chez des animaux au cours des 10 dernières années, on a construit un dispositif qui, installé chez un paraplégique, contrôle l'extension active des articulations de la hanche et du genou. En octobre 1982, on en a réalisé l'implantation chez deux paraplégiques; 6 mois après l'opération, les deux sujets ont appris à marcher avec des béquilles en se servant du dispositif. Au cours des 3 derniers mois, on a pratiqué la même intervention sur 2 autres personnes.

The nerve- and muscle-units of the legs in paraplegic patients with a cord lesion cranial Th-12 are still functioning, but are out of the patient's control. The idea of overbridging the spinal cord defect by an artificial electrical device seems to be obvious. The phenomenon of muscle contraction by electrical nerve stimulation is well known and becomes more and more intragrated into the therapy of paraplegics, mainly by extracorporally applied surface electrodes. Up to now intracorporally implanted nerve stimulation systems are connected with different problems and risks, as for instance electrically induced fatigue of muscles, dislocation of electrodes, damage of the implanted materials or the nerves with resulting loss of function.

1971 a fatigue-free stimulation method of nerves was developed in our Department, called "Karussell-Stimulation". In periodically switching the electrical current between 4 electrodes placed around the nerve, a marked time prolongation of fatigue-free nerve stimulation could be gained. The principle of the system is the periodical different submaximal stimulation of different fibre groups of the nerve with the possibility for periodical recovery of the not activated nerve fibres. In animal experiments the development of stainless steel electrodes for long time application as well as the development of electrical impulse forms to gain a smooth, strong and constant muscle contraction, were investigated. In other experiments the electrochemical and mechanical influence of the electrodes and a long time electrical stimulation to the nerve and muscles was investigated. The alterations of the nerve due to mechanical or electrochemical influence of the stimulation system was found to be kept within reasonable limits. After long time stimulation the musculature demonstrated a transformation of fast contracting muscle fibres into slow contracting type I fibres reflecting the adaptation to a more fatigue resistant type.

As a result of these experimental investigations stainless steel electrodes consisting of 17 monophiles with a diameter of 0.05mm twisted in a spiral design and covered with silicone rubber was developed. A battery driven portable 16-channel extracorporal control device measuring 170x180x30mm was constructed and connected with an inductive transmitting coil. An implant in a size of a commercially available cardiac pacemaker called "Transcutor" consisting of a receiver coil, electronic management and a connection leading to the electrodes was constructed. All parameters for optimal functional stimulation of peripheral nerves, which are impulse duration, frequency, current amplitude and shape of the pulse series can be programmed in the external stimulation device. Two crutches are equipped with two switches to give the patient the possibility of controlling his one way gait with two fingers of both hands.

The first clinical application of this stimulation system for functional electrostimulation with the goal of mobilisation of paraplegic patients was performed in October 1982. In two female patients, 22 and 41 years old, a complete spinal cord lesion was located between Th-9 and Th-12 caused by traffic accidents 21 years ago in the first and 4 years ago in the second case. In both patients the femoral nerves and infragluteal nerves were connected with 4 electrodes each to stimulate the quadriceps femoris muscle for knee joint extension and the gluteus maximus muscle for hip joint extension.

Operating procedure: a transveres incision was made in the gluteal region just above the foramen infrapiriformae. The infragluteal nerves were located and 4 electrodes were fixed to the epineurium of the nerve branches with 8/0 nylon. The electrodes were connected subcutaneously with the implant placed in the lower abdominal wall, 5cm medially of the iliac spine. Through another vertical incision in the groin region the femoral nerve was isolated and again connected with four electrodes in the same way. The fixation of the 4 electrodes on each nerve was done in a square position to perform a so called "Karussell-Stimulation". The postoperative period in both patients was uneventful and on the 10th postoperative day electrostimulation of increasing duration was started. The patients were told to stimulate their muscles three times daily for about 20 minutes and in regular intervals both patients were called to the hospital for follow-up studies. With the control part of the stimulation device the patients got the possibility to chose between 16 different modes of nerve stimulation by changing the electrical field between the 4 electrodes. Doing so, different parts of the stimulated muscles are activated and fatigue is retarded. During the first 3 postoperative months the stimulation currents of the different combinations changed markedly, but after 3 more months in both patients the stimulation currents became stable. During the postoperative training the muscle power increased markedly as it can be seen in Figure 1.

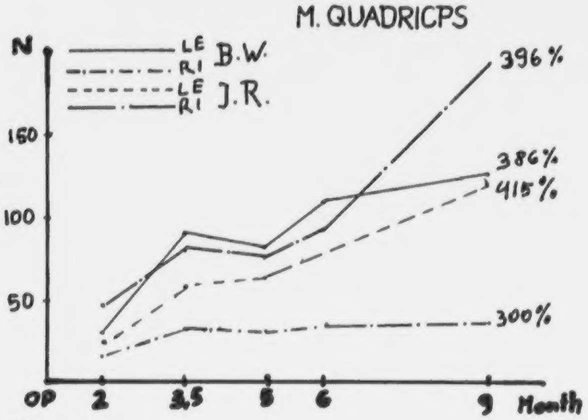

Figure 1

5 months after the operation both patients were called to the rehabilitation center in Bad-Häring / Tyrol to learn and train how to use their implanted stimulation system with the purpose of standing up and walking with the aid of crutches. One year after the operation both patients are now able to stand up from their wheel chair and walk about 100m with the aid of crutches (Figure 2).

In two other patients the same stimulation device has been implanted in November last year with similar results up to now.

Since our clinical results demonstrated no definitive technical or biological limiations for the application of the presented stimulation system we are encouraged going on with our research program, since there are still problems as for instance spasticity of muscles interferring with the functional stimulation or the wish to surmount a staircase. To realize these purposes the functional stimulation device has to be extended.

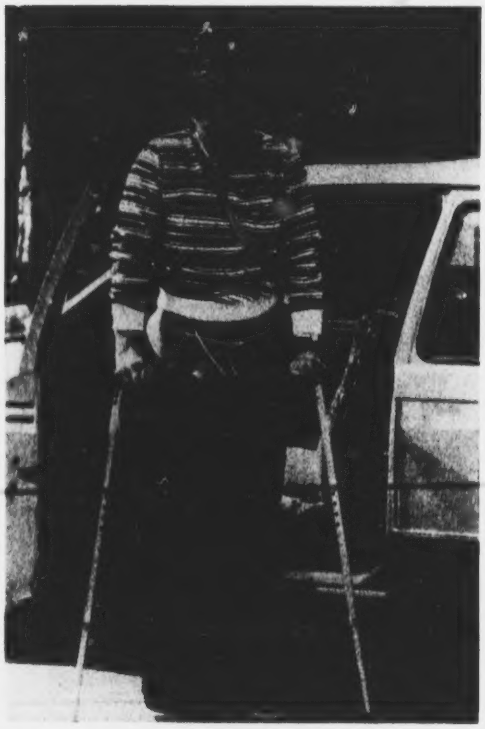

Figure 2

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QUANTITATIVE ANALYSIS OF STANDING BALANCE IN PARAPLEGIC INDIVIDUALS

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ABSTRACT- To determine the efficacy of KAFO braces and FES in providing postural stability for paraplegic individuals quantitative analysis of the center of force was performed. Four paraplegic individuals using these assistive devices for standing under a variety of conditions were tested, and seven neurologically normal individuals served as controls.

RÉSUMÉ- Afin de déterminer l'efficacité des armatures orthopédiques KAFO et FES pour assurer la stabilité du maintien pour les paraplégiques, il a été fait une analyse quantitative du centre do force. Quatre paraplégiques utilisant ces appareils d'assistance pour garder la station debout dans un certain nombre de circonstances ont été soumis à l'épreuve, et sent individus neurologiquement normaux ont servi de contrôles.

INTRODUCTION

Individuals with paraplegia are typically evaluated for standing as part of their rehabilitation. If certain criteria are met, knee-ankle-foot orthoses (KAFO) may be prescribed (1). However, KAFO are often rejected for a variety of reasons (2). It has recently been suggested that standing may also be achieved by these individuals using functional electrical stimulation (FES) (3,4,5). It is not presently known how the stability of quiet standing with KAFO or by FES compares to that of normal standing. We are concerned with comparing the performance of KAFO with FES, and the present study was undertaken to quantitatively evaluate standing performance under various conditions.

METHODS AND RESULTS

The most widely used method of assessing postural stability clinically is the Romberg test (6). Quantification of standing performance is typically done by measuring the movement of the center of force (COF), and displaying this movement on an x-y plot. Two measures have been suggested for this type of data - the mean amplitude (MA) and the sway path (SP) (7). The MA is the average length of a vector from the origin to an instantaneous point on the sway path and the SP is the total distance traversed by the COF during the measurement period.

A triangular platform with vertical load cells at each apex was constructed. The outputs of the load cells were processed by analog circuitry to give the x- and y-coordinates of the COF and the total vertical weight on the platform. The feet of the subjects were kept at a uniform position by means of a small trapezoidal block mounted on the surface of the platform. A stripchart recorder produced a continuous record of the COF coordinates and the total weight. A PDP 11/45 computer also digitized the COF coordinates and performed computations for MA and SP. The sampling rate was 100 Hz and 20 sec of data were taken on each trial.

Experiment 1: In this experiment, seven neurologically normal subjects were tested. The conditions tested were 1) eyes open, hands on bars (EOWH), 2) eyes open without hands (EONH), 3) eyes closed, hands on bars (ECWH), and 4) eyes closed without hands (ECNH). The average data (mean M and standard deviation SD) for the seven normals are summarized below.

NORMALS

		EONH	EOWH	ECNH	ECWH
SP	M	0.33	0.11	0.49	0.11
	SD	0.10	0.11	0.27	0.08
MA	M	1.59	0.23	2.27	0.29
	SD	0.52	0.25	0.91	0.27

Experiment 2: Paraplegic individuals were tested while standing in KAFO for the same conditions described in experiment 1. Some of the paraplegic individuals were unable to stand under those conditions without hands.

Experiment 3: Paraplegic individuals were tested while standing with bilateral electrical stimulation of the quadriceps muscles for the EOWH condition described in experiment 1. None of the paraplegic individuals were able to stand by FES without hands for the twenty second data collection period. Data for experiments 2 and 3 are summarized below. The data are averages from four paraplegic individuals.

KAFO

		EONH	EOWH	ECNH	ECWH
SP	M	0.27	0.19	0.72	0.48
	SD	0.09	0.19	0.49	0.08
MA	M	2.68	0.99	10.28	2.93
	SD	0.97	0.73	7.64	1.09

FES

		EOWH
SP	M	0.36
	SD	0.21
MA	M	3.25
	SD	2.12

DISCUSSION

The purpose of this study was to quantitatively measure standing performance in paraplegic individuals under a variety of conditions. There are a number of quantities which could be measured to indicate standing performance but the two measurements used in this study appeared to best express standing performance (7). They do not address the postural configuration that was assumed by the body segments, nor do they indicate what types of forces were applied by the upper extremities. They do indicate how well the COF was controlled about its mean operating point within the base of support provided by the feet.

The main sensory systems involved in maintaining posture are the visual, vestibular, and proprioceptive systems (8). We studied the effect of vision on standing performance and found that whenever hands were not used, both SP and MA increased when eyes were closed. When hands were used, normals showed no differences between EO and EC, while paraplegic individuals standing by KAFO had marked differences between EO and EC. These findings have implications for the necessity of providing supplemental sensory feedback to paraplegic individuals standing by various assistive means. The data also clearly show the importance of the hands in postural stability. In all cases studied, standing performance was improved when hands were used for balance.

FES of the lower extremities to achieve standing in paraplegic individuals has been suggested as a possible alternative to KAFO braces (3). FES has the advantage of using the patient's own neuromuscular system for support and is less cumbersome to use. If FES is to replace KAFO, it must also provide a comparable degree of safety and stability. In order to assess this hypothesis, we compared the postural stability attained with KAFO with that provided by FES. We found that the standing performance achieved with FES in our group of paraplegic individuals was somewhat less than that provided by KAFO. Present work centers on correlating quantitative measures of standing performance with subjective impressions of postural stability and safety.

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TECHNOLOGY OF IMPLANTS IN PARAPLEGIA PATIENTS*

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ABSTRACT - Four paraplegia patients were equipped with new implantable multichannel stimulation usable for every day's practice to make them stand up and walk a short distance with the help of crutches.

RÉSUMÉ - Quatre paraplégiques ont reçu un nouveau système de stimulation implantable à cannaux multiples pour utilisation quotidienne leur permettant de se lever et de marcher sur une courte distance à l'aide de béquilles.

INTRODUCTION

Demands to an implantable nerve stimulation device are very high /1/, all stimulation parameters have to be adjustable in real time, the system has to have the ability to stimulate several electrodes (multichannel), battery supply is uneffective because of the high current demand. Because of the high electronical expenditure of the implant and the question of safety we aimed at a solution using hybrid technology.

DEVELOPMENT

Up to now the result of our developments is an 8-channel stimulation device which is able to stimulate two nerves via four electrodes each.

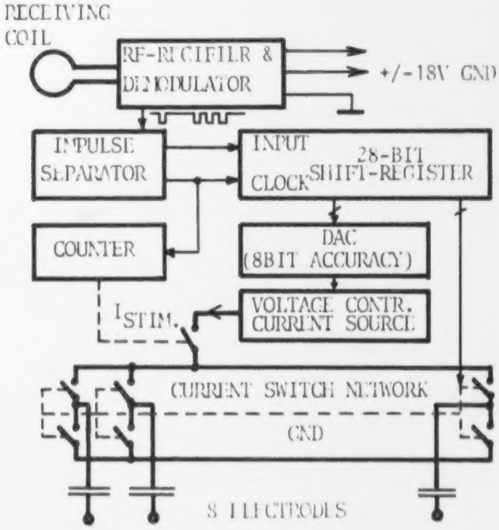

Figure 1: Blockdiagram of the 8-channel nerve stimulator which was implanted in four patients

Fig. 1 gives an impression of the complexity of the implant. Technical data are the following /2/:

./. stimulation current adjustable up to 8 mA in 256 steps (quarter percent resolution);
./. constant current stimulation (so voltage drops at the nerve-electrode connection is neglectable);
./. max. voltage is 15 Volts;
./. polarity of stimulation impulses is chooseable;
./. stimulation impulse width is adjustable continuously up to 2msec;
./. stimulation frequency is also adjustable (e.g. 20 Hz-100 Hz);
./. selection of active electrodes is arbitrary;
./. voltage supply of the implant as well as information transmission is done by RF-coupling transcutanuously using an extracorporal transmission coil;
./. exact positioning of the transmission coil is not important, all parameters are independent of distance (up to 100 mm).

It is very important to point out, that all necessary information concerning stimulation parameters is transmitted anew preceding each stimulation impulse. This is essential for functional electrostimulation where movement has to be adaptable at any time. Beside this we are using a time multiplexing method. the two nerves connected to one implant are stimulated alternating each impulse. Information transmission is done by means of a digitally coded sequence (fig. 2), which is modulated on the RF-carrier (27 MHz). Decoupling capacitors in all output lines to the nerve prevent DC-current. The size of the implant is compareable to a heart pacemaker /3/.

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*) Supported by the Austrian Research Foundation and the AUVA

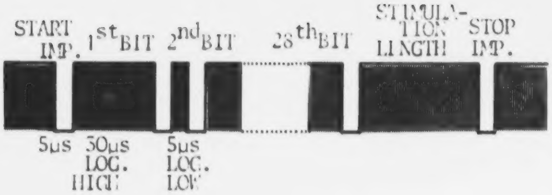

Figure 2: Modulation sequence of transmission of parameters preceeding each impulse

The external control unit is battery powered (rechargeable) and is able to supply two implants via two transmission coils = 16 channels. Control is done by means of a CMOS-microprocessor. According to the principle of the "roundabout electrode" all electrode combinations have to be stimulated with adequate current. To allow easy programming there is an alphanumeric display. Electrode combinations which are not working sufficiently can be deleted. Once programmed. all data remains stored using a CMOS-RAM. The size of the control unit is 17x12x6cm. We developed two versions of these control units. One is for electrostimulation of extremities (control is done by an especially designed joy-stick), the other one is for electrophrenic respiration (built-in generator for breath frequency and inspiration duration).

RESULTS

In October 1982 two eight-channel units were implanted in 2 paraplegia patients, in November 1983 another 2 patients /4/. All technical systems were in function during the first year, but we lost one electrode in the first post operative day, because of disconnection of the nerve. After the first year we had to change 2 implants because of technical problems. One implant had a failure of a bond-connection, the other a corrosion due to a breakin of fluid via the connector. Both implants were exchanged easily in the same way like usual pacemaker changes. Stimulation parameters were changed only in the first 3 months due to biologic -eaction against the electrode. After this period stimulation current is constant in the range of less than 3 mA for the m.quadriceps and less than 5 mA for the m.glutaeus. Stimulation frequency is 30 Hz, stimulation impulse duration is 0.6 ms. We tried to reduce this parameters, but with the effect of less force. Due to our special stimulation method amplitude increase of stimulation current recruits successive more nerve fibres we achieve a smooth movement. Standing up we switch to the maximum of the preadjusted stimulation current, due to weight acceleration even in this treatment a smooth movement can be observed. After the 3 month the optimum of stimulation current is adjusted only during follow up studies in the range of 2 months.

DISCUSSION

All four patients have accepted the disadvantage of the invasive method and the necessity to change an implant in case of failure.

The failures of the first generation of implants has proofed the effectiveness of careful testmethods to assure a reliability growth. This will be an important point for further research in the near future.

The overall question of this new method is the practice /5/. It is our experience that if we are not able to offer special features and possibilities during every day's practice the handicapped will persist in the wheel chair. Therefore we have to offer in the near future a stimulation device built in a belt with a check-up time less than half a minute and to define a list of duties necessary for every day's practice as e.g. check in busses, railways or aircrafts without any other personal help.

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SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 24

TECHNOLOGY FOR THE HEARING HANDICAPPED II/
TECHNOLOGIE POUR LES MALENTENDANTS II

MACHINE SHORTHAND TRANSCRIPTION USED AS AN AID FOR THE HEARING IMPAIRED AND IN COMMERCIAL ENVIRONMENTS

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ABSTRACT - Automatic transcription of Palantype shorthand has been used for some time as a verbatim transcription aid for the deaf. Recent advances have combined the requirements of this system with those of court reporting to the mutual benefit of both applications.

RÉSUMÉ - Depuis quelque temps déjà, on utilise la transcription automatique de la sténographie Palantype pour informer mot à mot un sourd de ce qui est dit. Les derniers perfectionnements ont permis de combiner les exigences de ce système à ceux de la sténographie judiciaire, pour le plus grand avantage de ces deux applications.

EARLY TRANSCRIPTION FOR THE HEARING IMPAIRED

In 1977 the British Member of Parliament Jack Ashley was the first deaf person who was able to simultaneously read a verbatim version of what was being said to him (Newell). The device which enabled him to do this was a transcription system attached to a palantype shorthand machine. A trained stenographer listened to what was being said and recorded it in the same way she would normally do, if working in a law court for example. However, switches had been added to the keys of this machine and an electronic system transcribed the output from the palantype code into a more readable form and displayed this on a visual display screen. The output of the device was not easy to read and thus the system was only appropriate for a highly motivated individual.

The original palantype transcription system was built of hardwired digital logic. Since then microcomputer technology has been used to enhance the system, both in terms of the quality of the output and its flexibility. In 1979 the system was replaced by a microcomputer based version with a dictionary of approximately 1400 words. This ensured that approximately 70% of the output was correctly spelt; words which did not appear in the dictionary were transliterated into easily read, if not correctly spelt English. Both Mr. Ashley and a deaf businessman have used systems of this kind very effectively since that time (Hayward). The improved output quality meant that a much greater range of people could benefit from the system although, of course, a trained operator was required. This system has been successfully used in meetings and lectures for hearing impaired people as well as in a very successful trial of a telephone bureau for the hearing impaired (Grossfield).

When using the telephone bureau people would make telephone calls to hearing impaired people via a Palantype operator in a central bureau. The operator would transcribe what they were saying, and the message would be transmitted to appear on a viewdata terminal in the hearing impaired person's home.

Both standard typewriter and Palantype keyboards were used in the trials - the advantage of Palantype being that the calls took less time and, because the palantype machine can be operated at verbatim speeds, the conversation had an immediacy and intimacy which was lost in the slow prècis which could be given using a typewriter keyboard. One deaf person remarked "it was just like listening to my son". Pilot studies were also conducted on the use of such a system for subtitling live television programmes (Baker et al).

COMMERCIAL USES FOR THE SYSTEM

As with many aids for the handicapped, although the system was successful, its commercial viability was questionable. It was therefore decided to upgrade it so that the output quality and facilities offered were appropriate for it to be used in a commercial environment (i.e. to automatically produce verbatim records of meetings etc.) This was achieved by increasing the dictionary size to over 10,000 woards and adding a facility for personalising the dictionary both for individual palantypists and subjects. Special purpose text editing and file handling facilities were also added.

The applications for the hearing impaired were not forgotten, however, and care was taken to ensure that the system could work in real time and thus produce a simultaneous transcript when required. A large screen projection television was added specifically for this use in meetings. The improved quality of the output script meant that anyone with normal reading skills could understand the output, and thus a much larger range of hearing impaired people could benefit from the system (although, of course, pre-lingually deaf people with poor linguistic skills may not be able to read the script presented) (Downton et al). The output is not perfect because very uncommon words are not in the dictionary and also because of operator errors, but over 95% of the output words are correctly spelt. The script is not only easily readable, but its quality is sufficiently high to provide a perfect transcript economically by editing the script using a word processor.

The advantages of this provision were shown at a recent meeting which had a number of hearing impaired delegates present. A service was provided for the hearing impaired - they could read every word that was being spoken on the large screen monitor, and they commented very favourably on the value of this service to them. In addition however, a recording was being made both in an electronic form and on paper. Thus, at the the end of the meeting, delegates could take away a readable draft of the proceedings and later the electronic version of this draft could be edited to produce a perfectly spelt verbatim report of the meeting. (A text editor had been specially developed to provide a highly efficient editing environment for palantype transcripts).

It was clear that these facilities made this system very appropriate for use in many situations and in particular the law courts - a verbatim record is usually required in a court of law, and the use of a palantype transcription system offers extra facilities for a negligible extra running cost:

(1) the provision of a service for the hearing impaired people in the court
(2) an immediate rough transcript, and
(3) a much more efficient method of providing a final transcript than the normal one of typing from a shorthand writer's note.

The current palantype transcription systems require floppy discs to store the dictionary data and are not in a portable form. They are being marketed initially to the reporting firms with the primary aim of providing a more efficient system for producing transcripts. Longer term plans include their use in the electronic office. Miniaturisation will enable products to be produced which are portable and thus more widely useful in the deaf community.

AMERICAN SYSTEMS

The American stenograph system is similar to the palantype system and a number of CAT (Computer Aided Transcription) systems have been developed for commercial environments. However, our studies showed that, due to the coding conventions of Stenograph, it was more difficult to produce a low-cost portable Stenograph aid for the hearing impaired (Arnott et al). In America the commercial applications of Stenograph have been to the fore, whereas in Britain automatic transcription was successfully applied as an aid for the hearing impaired before it was used in a commercial reporting environment.

CONCLUSIONS

A palantype transcription system requires a trained operator and thus it will never be a universal panacea for hearing impairment. Nevertheless it has an important place, and the combination of an aid for the hearing impaired and a commercial viable system for producing reports of meetings will ensure much wider availability of the system than if it had been designed and marketed exclusively for the hearing impaired.

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TONESCRIBER - A NOVEL COMMUNICATIONS SYSTEM FOR THE HEARING IMPAIRED

George C. Arrowsmith, Robert E. Larson and C. Gerald Warren

ABSTRACT - The TONESCRIBER Communications System records and displays plain text messages originating from any touch-tone telephone. It also dials the telephone; sends as-typed or pre-recorded messages to one or a list of telephone numbers which are also equipped with a TONESCRIBER; interprets coded messages; participates in a 2-way dialog with another TONESCRIBER; and can be used as a powerful personal computer.

RÉSUMÉ - Le système de communication TONESCRIBER enregistre et affiche des messages en clair envoyés par un poste téléphonique à clavier "Touchetone". En outre, il compose le numéro; achemine un message que l'on vient d'écrire ou un message pré-enregistré à un poste ou une liste de postes, également dotés d'un TONESCRIBER; interprète des messages codés; soutient un dialogue avec un autre TONESCRIBER; et peut faire office d'un puissant ordinateur personnel.

INTRODUCTION

The TONESCRIBER was developed in response to the obvious necessity of being able to communicate with a hearing impaired person, over the telephone, without benefit of a seventy pound teletypewriter, an acoustic coupler, a roll of paper, and a 110 volt convenience outlet, all of which are rarely found in the corner telephone booth. What you are likely to find in that phone booth, however, is a touch-tone keypad, and that is a fundamental ingredient of the TONESCRIBER system.

A MARRIAGE OF MODERN TECHNOLOGIES

The hardware components of the prototype TONESCRIBER terminal consist of an inexpensive personal computer, either a Commodore-64 or Commodore VIC-20, a circuit board that is plugged into either of those machines, a cord that is attached to the circuit board and terminates in a common modular telephone connector, and a television set that is plugged into the computer. The personal computer is certainly modern technology. At least one of the integrated circuits on the circuit board is very high technology: a one-chip DTMF (Dual Tone Multi-Frequency, or Touch Tone) decoder. This chip which replaces an entire circuit board full of transistors, coils, capacitors, trimmers, etc., converts analog Touch-tone signals into a digital format that is usable by the computer. Only one chip, as well, is used for generating the analog Touch-tone frequency pairs from the digital data produced by the computer. Notwithstanding the fantastic capabilities of these modern technologies, what is truly amazing is their size and COST. A packaged computer, with power supply, full typewriter keyboard, serial, parallel, and joystick interfaces, composite video output that will directly drive a television set, sound generation, graphics, a time-of-day clock, a complete BASIC language interpreter, etc., FOR UNDER SEVENTY FIVE DOLLARS.

TONESCRIBER CIRCUIT BOARD

The TONESCRIBER circuit board provides the interface to the telephone line, which includes line control (on-hook and off-hook), ring detection, and A-D and D-A conversion, and contains the software in read-only memory and the associated address decoding circuitry. The circuit board is packaged in a cartridge, just like a youngster's game, but with a telephone cord umbilical. Whenever the TONESCRIBER cartridge is plugged into the computer's expansion port edge connector, the on-board software takes control of the machine; the computer is restored to a factory-spec machine by removing the cartridge. Line control is accomplished by a normally-open relay that is managed by a timer that restores the on-hook condition unless it is discretely re-triggered at five second intervals. As a result, normal telephone service is not affected by loss of power to the computer or removal of the cartridge from the computer.

TONESCRIBER COMMUNICATIONS PROCEDURE

The TONESCRIBER communications procedure involves both a message protocol and a character encoding scheme.

Message Protocol

A. All messages start witn an asterisk(*).
B. The body of the message is arbitrary.
C. All messages end with either #1 or ##, depending on whether or not a response is expected.

Character Encoding Scheme

If the TONESCRIBER keyboard is being used then the computer automatically sends a pair of touch-tone signals for each keystroke. If a telephone keypad is in use, then two keystrokes are required for each character. The encoding scheme is as follows:

1. Numbers - a number character is encoded with the digit zero (0) followed by the desired

digit. For example, the number '9' is encoded with '09'.

2. Alphabetic Characters - For the purpose at hand, each alphabetic character on the touch-tone keypad is viewed as having two important attributes: its physical location on the keyboard, and its relative position in its row. Those two attributes are invoked, in that order, in encoding character representations. For instance, the letter "A" is found on the "2" key and it is the left-most of the three letters "ABC". Therefore, the code for the letter "A" is "21"."2" because "A" is printed on the "2" key, and "1" because it is the left-most key in the row that contains the character "A". The letter "R" is encoded by "78": "7" because "R" is found on the "7" key and "8" because "R" is in the middle position of the "PRS" key and "8" is in the middle position in the row. Similarily, "V" is represented by the two-key entry "89". While"Q" and "Z" do not appear on the keyboard, an equally simple rule has been devised for their encoding as well.

3. Punctuation - The first entry for all punctuation symbols is "1". The second entry is the first letter of the symbol name. Examples include: "1C" for comma, "1H" for hyphen, and "1P" for period.

The code is easy to learn and with a little practice, reasonable speeds can be attained.

OPERATING SCENARIOS

Receipt of Message from a Touch-tone telephone

A message can be sent to a TONESCRIBER from any Touch-tone telephone. The target telephone number is dialed and the TONESCRIBER will answer the call after a (user) selected number of rings (the called party need not be present). The message, sent according to the procedure cited above, is stored in the computer and displayed on the television screen on demand and/or as it is received. Using the clock contained in the computer, all incoming messages are time and date stamped.

Communications Between TONESCRIBERS

A call can be originated by a TONESCRIBER operator to another such unit. When the target number answers, a 'hello' message appears on the originator's screen and the originator may use the keyboard to type a message which will appear on the called party's screen (and/or stored in the computer memory). If the called party is present, a two-way conversation may transpire between senders keyboard and receivers television screen.

Unattended Message Sending

An originator may locally store a message(s) in the computer and direct that computer to place a call to a designated telephone number(s) at a specified time, say when long distance rates arelow. One message may be stored with several destination telephone numbers, or several messages may be stored, each with a unique destination telephone number.

FUTURE ENHANCEMENTS

The developers recognize that there are a host of installed machines that use alternative telecommunications technologies, predominately FSK 5-level Baudot coding. Still others use FSK 8-level ASCII. An enhanced version of the TONESCRIBER is being developed to accomodate those alternative communications technologies as well as TOUCH-tone. Also being developed on the basis of the original TONESCRIBER concept is a low cost general consumer-oriented electronic mail terminal.

CONCLUSION

With the advent of the TONESCRIBER, anyone can deliver a telephone message to a hearing impaired person with no equipment whatsoever except a Touch-tone telephone.

A REVIEW OF A DECADE OF EFFORT TOWARDS IMPROVING USE OF THE TELEPHONE BY THE HEARING IMPAIRED

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ABSTRACT - This paper summarizes the involvement of Bell Canada in efforts to improve telephone communication by the hearing impaired since 1974.

RÉSUMÉ - Cette communication résume la participation de Bell Canada depuis 1974 dans les efforts pour améliorer la communication par téléphone des malentendants.

The research programme described herein was initiated by internal suggestions made at the time Bell Canada was evaluating a new general purpose telephone receiver, the Balanced Armature Receiver (BAR), intended to replace the more costly, less efficient U-type receiver. The new receiver produced significantly less magnetic flux than the old one and it was suggested that this was of importance to the hearing impaired in their use of the telephone.

Knowledge and understanding of the use of the telephone by the hearing impaired was virtually nonexistent from internal resources. Seeking to determine the nature and extent of the potential problems, meetings were held with representatives of the major organizations representing the hearing impaired in Ontario and Quebec--the operating territory of Bell Canada. The response from these various organizations varied widely, from an inability to be of any assistance because their members were generally those who did not use the telephone to any extent and they consequently had no facts, to the position that removal of the significant leakage flux would be tantamount to removing the ability to use the telephone from the entire hearing impaired community. It quickly became apparent that no quantitative data was available.

With the object of determining the situation in as factual and quantified a manner as possible, two surveys were conducted during 1975 with the assistance of a private market research organization. The first survey interviewed 201 people, roughly equally divided between the cities of Toronto, Montreal, and Ottawa, which were considered to be the locations of the people most likely to be affected. The aim was "to determine the profile of the Hard of Hearing Telephone User" and addressed hearing impaired people who claimed to make use of the telephone, which included a wide age range incorporating a proportion of employed people. Use of the telephone ranked sixth in difficulty in a series of ten situations in which hearing aids are used. Roughly 40% used magnetic coupling, 20% used acoustic coupling, 25% did not use their hearing aid when using the telephone, and 10% did not use the telephone at all. The second survey was conducted across Canada in conjunction with a much larger consumer survey. 187 individuals who used hearing aids were identified. This indicated that the incidence of hearing aid ownership is about 7.3 per 1,000, or 0.73%. Half the owners are over 65 years of age and four in five are 45 years of age or over, with very few owners being active in the work force. 14% did not use the phone at all, 35% used their hearing aid with the telephone, and 57% did not use their hearing aid when using the telephone.

In the meantime, discussions and negotiations had been taking place between Bell Canada and a group of 23 organizations representing the hearing impaired in Ontario. In November 1976, an agreement was reached that Bell Canada would proceed with the introduction of the BAR, but would at the same time retain an equivalent leakage magnetic flux in all public pay phones, in all telephones which would be used significantly by hearing impaired people, and in any other telephone on request at no charge. Also, Bell Canada would offer a portable acousto-magnetic coupler at a nominal charge and would embark on a programme of research to improve the use of the telephone by the hearing impaired.

The programme of research was initially conducted by Bell Northern Research Ltd. (BNR). Given that the two instruments involved were both electro-acoustic devices , they concentrated on the possibility of coupling them together acoustically. Three alternative approaches were evaluated in the laboratory and a method which extended the input of the hearing aid microphone via a tube to a location on the wearer's cheek where a "tighter" acoustic coupling was possible was selected as the most promising. This became known as a "tube-microphone." A trial of this approach in the traditional telephone company manner was conducted with about 100 participants. The trial was a failure as, despite much organization, upwards of 50% of the participants did not follow the laid down procedures. No conclusion was possible.

Aiming to obtain guidance for the research programme, a conference was held with three independent consultants in February 1979. The consultants were recognized experts in the fields of acoustics, hearing aid design and manufacture, and hearing impaired research. They supported the continuation of our efforts, but suggested a more clinical approach be used, a suggestion which has since been followed. At about this time, a contact was made with representatives of the Hearing Aid Manufacturer's Association (now Hearing Industries Association) under the auspices of the Electronics Industries Association (EIA), with relatively little result.

Realizing that to follow a more clinical approach, as had been suggested, new instrumentation would be required, BNR initiated the development of the Audiometer Telephone Interface (ATI). This device allows all the traditional audiometric methods of testing, evaluation and prescription to be followed when using a telephone. The ATI simulates an average telephone network connection, including the far end telephone, and provides the necessary electrical conditions for a regular telephone set to be used by a hearing impaired person, with or without their hearing aid, in any desired manner in a clinical test environment. The ATI has been the basis of all of our subsequent subjective evaluation work. The ATI was described in an article in Hearing Instruments in June 1982.

The ATI was available in May 1980 and has been used since then in the research programme to evaluate the relative merits of alternative approaches the hearing impaired employ when using the telephone. Evaluation has also been done of a number of strategies and modifications which could conceivably improve the use of the telephone by this population. Greater details on this research programme will be given in companion papers by Richard Stoker and Marilyn French-St. George of The Pennsylvania State University.

Outside of the domestic situation, work was being done by experts in the International Electrotechnical Commission (IEC) to recommend much needed standards for Hearing Aids. This work will be summarized by Dr. Wojcik in a companion paper.

Bell Canada's programme is continuing, as is the work in IEC and CCITT. Recently, the Federal Government has become more active as a result of an approach to Cabinet by representatives of the Hearing Disabled Community. An ad hoc committee has been formed by the Department of Communication to include representatives of all interested parties to discuss and report on this subject matter. The Canadian Standards Organisation has also undertaken to recommend standards in this area.

The paper, when presented, will include any subsequent developments to provide an up-to-date situation report on the work being done to ensure that the best possible opportunities are made available to the hearing impaired when they wish to use the telephone.

REVIEW OF CANADIAN AND INTERNATIONAL STANDARDIZATION RELATED TO COUPLING OF HEARING AIDS AND TELEPHONES

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ABSTRACT - National and international standards are discussed in relation to telephone sets, hearing aids, and telephone/hearing aid coupling. A consideration of all possible methods of coupling hearing aids to telephones is now under-way in IEC/WG 17 and CCITT/SG XII; latest contributions to this work are summarized. Reference is also made to a standard proposed by the Electronic Industries Association for the magnetic field strength of telephone receivers, which is being reviewed by CSA. It is doubtful whether telephones complying with this standard would provide for the adequate magnetic coupling of hearing aids.

RÉSUMÉ - On discute des normes nationales et internationales en ce qui concerne les appareils de téléphone, les prothèses auditives et le couplage entre le téléphone et ces prothèses. Le IEC/WG17 et le CCITT/SGXII étudient présentement toutes les façons possibles de coupler les prothèses auditives au téléphone; on résume les derniers développements dans ce domaine. On fait également allusion à la norme proposée par l'Electronic Industries Association, et étudiée par l'ACNOR, au sujet de la force du champ magnétique des récepteurs téléphoniques. Il est douteux que les téléphones conformes à cette norme puissent permettre un couplage magnétique acceptable des prothèses auditives.

SUMMARY

Three technical standard areas are of interest from the point of view of the compatability of hearing aids and telephones: 1) telephone transmission performance, 2) hearing aid performance, 3) telephone and hearing aid interface parameters.

In the past, all telephone sets and other terminal equipment were provided by the telecommunication carriers, who had their own comprehensive specifications governing the network harm, performance and quality of equipment (e.g. Bell Canada DS 8610 and Bell System PUB 48005). This situation has changed in North America with the advent of terminal attachment, which permits the user to purchase or lease his terminal equipment from any supplier once the equipment has been type approved.

The industry has recognized a need for terminal equipment standards. In Canada, this work has been undertaken by a newly formed telecommunications committee of the Canadian Standards Association (CSA): the U.S. Electronic Industries Association (EIA) is also active in the telecommunications area (e.g. RS-470). The standards published by these two agencies are developed by a consensus process involving all interested parties and are voluntary within the industry.

Most of the IEC documents related to hearing aids were prepared by experts in Working Group 6 in Technical Committee 29. The current task of this Working Group is considered to be completed and the Working Group was disbanded at the last Plenary Meeting of the TC 29 in Paris, July 1983. The remaining task, being an interfacing of hearing aids with telephones, is assigned to the working group W.G. 17 formed recently.

Most industrialized countries have their own national standards related to hearing aids. In many cases, the national standards are derived from IEC recommendations, complemented with some performance requirements and often enforced by local government authorities.

In the United States, an equivalent of the IEC II8 series was prepared by the American National Standards Institute and was newly revised as ANSI Standard S-3.22-1982.

A significant increase of interest in the problem related to the coupling of hearing aids and telephones was demonstrated by the submission of several contributions simultaneously to the CCITT/SGXII and to the IEC/WG17. Experts involved in the study on Question 23/XII are divided into two groups. One is supporting design practices leading to implementations accepted as satisfactory by hearing aid users. The second group, concerned with the lack of acceptable implementation in their countries, supports "ideal" magnetic performance of the receiver. This performance is derived from similar but not analogue scenarios and will not necessarily lead to better user acceptance. On the contrary, variation of the signals in the telephone line can overload hearing aids and decrease comprehension, and the frequency response of the signal presented with both magnetic and acoustic coupling is not well understood.

Introduction of a standard for magnetic field around the telephone receiver seems to be needed at this point in time.

A COMPARATIVE EVALUATION OF THREE TELEPHONE COUPLING METHODS FOR THE HEARING IMPAIRED IN THE PRESENCE OF COMPETING BACKGROUND NOISE

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ABSTRACT - This study compares three methods used by hearing impaired users for telephone communication: acoustic coupling, magnetic coupling, and an amplifier handset. Nearly 300 subjects participated in the study which showed that the amplifier handset was the single best coupling method.

RÉSUMÉ - Cette étude compare trois méthodes utilisées par les malentendants pour communiquer par téléphone: couplage acoustique, couplage magnétique et combiné amplificateur. Une étude à laquelle ont participé près de 300 sujets a démontré que le combiné amplificateur constituait la meilleure méthode de couplage.

INTRODUCTION

The development of the Balanced Armature Receiver as an improvement in general telephone equipment eliminated the strong magnetic field which had been commonly used to magnetically couple telephones and hearing aids equipped with a Telecoil.

An earlier study has shown that speech intelligibility over the telephone varies in a complex way when different levels of hearing loss and coupling methods are investigated. In general, the more severe the loss, the more crucial the coupling mode.

PRESENT STUDY

This research was aimed at answering the following questions:

1. Is there a clearly superior telephone-to-hearing aid coupling method for all hearing impaired persons?
2. Does the efficiency of common telephone coupling methods for the hearing impaired vary as a function of hearing loss and ambient noise levels?

METHODS

Subjects (279) were tested on three coupling modes under two background noise levels (86 and 76 dB SPL). The coupling methods were:

1. Telephone, without hearing aid, but with amplification adjustable to MCL (maximum of 106 dB SPL) thus simulating the amplifier handset
2. Magnetic coupling: U-1 receiver used with a hearing aid on "T" position
3. Acoustic coupling: receiver used with a hearing aid on "M" position.

The hearing aids used were the Unitron 205A for the normal and moderately impaired subjects and the Fidelity F39 for subjects with severe loss.

Subjects' oral responses to the SPIN (Speech Perception in Noise) test were recorded and percentage word correct scores were calculated.

SUBJECTS

I. Hearing Loss Categories
    A. Normally hearing, N = 74
    B. Moderately impaired, N = 111 (between 45-70 dB HL)
    C. Severely impaired, N = 94 (greater than 70 dB HL)

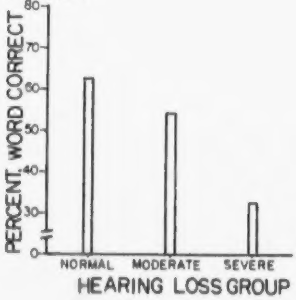
II. Criteria for hearing impaired subjects
    A. Hearing aid user for at least 2 months
    B. Habitual telephone user
    C. Hearing level of 45 dB HL or worse in better ear
    D. No history of unusual or fluctuating hearing loss.

(Normally hearing subjects were equated with the hearing impaired on the basis of age and sex.)

RESULTS

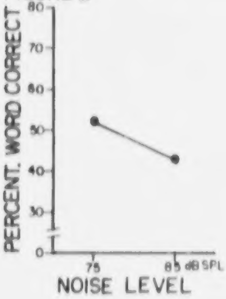
The data were subjected to analysis of variance procedures and three main effects were observed: hearing category, noise level, and coupling device.

FIGURE 1



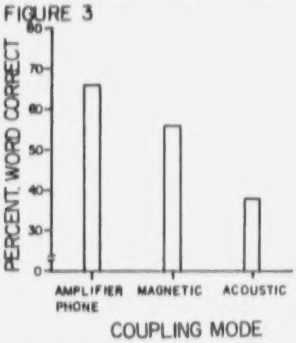
Scores became poorer as a function of hearing loss.

FIGURE 2



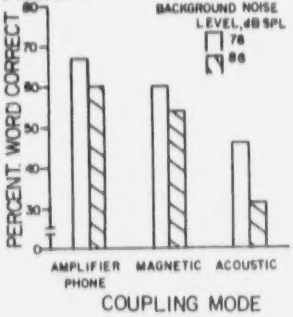
On the average, the high noise conditions caused scores to drop by 10% compared to low noise.

FIGURE 3



Phone only and magnetic modes were significantly better than acoustic coupling.

FIGURE 4



Noise level has a more pronounced effect on the acoustic mode than on the phone and magnetic coupling modes.

CONCLUSIONS

The results from this study suggest that when background noise is high, magnetic coupling of the telephone to hearing aids is the overall best method for most moderately and severely hearing impaired users, when a telephone with an amplifier handset is unavailable.

An increase in background noise level from 76 to 86 dB SPL impairs speech discrimination to a greater degree under the acoustic coupling mode compared to either magnetic coupling or amplifier handset use.

The severely hearing impaired subjects performed significantly poorer under all listening conditions compared to the normally hearing and moderately hearing impaired listeners.

SIGNAL LEVEL EFFECTS ON THE INDUCTIVE COUPLING OF HEARING AIDS AND TELEPHONE RECEIVERS

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ABSTRACT - This study is on the effects of various signal strengths on several types of telephone receivers used for magnetically coupling telephones and hearing aids. Reasons for the differences in subjective performance are discussed.

RÉSUMÉ - Cette étude porte sur les effets de diverses forces de signal sur plusieurs types de récepteurs téléphoniques utilisés pour le couplage magnétique des téléphones et des prothèses auditives. On discute des raisons expliquant les différences dans le rendement subjectif.

INTRODUCTION

Previous research has shown that hearing impaired telephone users tend to discriminate speech transmitted through a telephone better when using magnetic (inductive) coupling of telephones and hearing aids than using current acoustic coupling methods. Even though many hearing aid users do not use the magnetic (or "t-switch") mode and many hearing aids are manufactured without telecoils, magnetic coupling seems to be almost synonymous with telephone use by the hearing impaired.

Recent regulatory rulings have bowed to pressure from advocacy groups who insist that magnetic coupling is best, even though little empirical evidence can be brought to bear to prove their case. The telephone companies are now generally required to provide receivers which are "compatible" with telecoils despite there being no established guidelines as to what constitutes acceptable "compatability."

PRESENT STUDY

The research presented here will address four major questions:

1. Is there an optimal size, location, or sensitivity for hearing aid telecoils when used with telephone receivers?
2. What is the range of speech recognition performance experienced by hearing aid wearers using telecoil equipped hearing aids with three commercially available telephone receivers?
3. Is the balanced armature receiver with coil (BARC) equivalent to the traditional U-1 receiver in terms of hearing aid user performance?
4. Does the Acousto-Magnetic Coupler, produced by Northern Electric, produce speech recognition scores comparable to those obtained with the U-1 or BARC receivers?

INSTRUMENTATION

Ten subjects could be evaluated at one time. The signal level output at each subject's listening station could be adjusted to produce the following sound pressure levels at 1000 Hz: 80 dB (setting 1), 85 dB (setting 2); 90 dB (setting 3), 95 dB (setting 4); and 105 dB (setting 5).

EXPERIMENTAL DESIGN

Within each hearing loss group the experimental design may be described as a three-way analysis of variance with repeated measures (Fig. 1). Each subject was required to write down the words they heard at each of five different signal levels with four receiver conditions and three hearing aids (Table 1). Half lists of the NU6 word lists were used as stimuli.

FIGURE 1

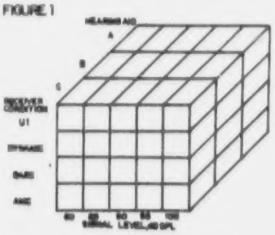
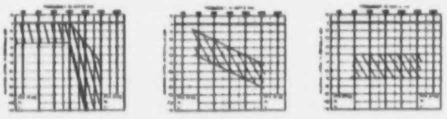


TABLE 1. Summary of Telecoil Characteristics of Nine Hearing Aids Used in the Study

Subject Group	Hearing Aid	Location in Case	Orientation in Space*	Core Construction	Construction Type/Dimensions
1	Unitron [illegible]	Medial/Dorsal	vertical	metal-wire	round, 10.5 x 1.5 mm
1	Danavox [illegible]	Medial	30° from vertical	metal-tab	squared, equal 6 x 4.0 mm
1	Beltone [illegible]	Medial/Dorsal	vertical	metal-wire	round 17 x 1.5 mm
2	Fidelity F-[illegible]	Inferior/Ventral	10° from vertical	metal-wire	round 8.5 x 2.2 mm
2	Siemens [illegible]	Medial/Dorsal	vertical	metal?-tab	squared, long 17 x 1.5 mm
2	Unitron [illegible]	Medial/Dorsal	10° from vertical	metal-tab	rounded 14 x 1.1 mm
3	Phonic Ear [illegible]	Inferior	**	metal?	square, thin, epoxy enclosed 6.5 x 0.5 x 1.5
3	Philips [illegible]	Superior/Ventral	15° from vertical	metal-wire?	rounded cylinder 11.5 x 3 mm
3	Zenith Vocalizer [illegible]	Superior	[illegible]° from vertical	metal?-tab	equal, encased cylinder 8 x 3 mm

SUBJECT GROUPS



n = 12 adults n = 12 adults n = 12 adults

RESULTS

1. Within a hearing loss category, no significant effect for hearing aid type was observed.

2. Significant main effects (α = 0.01) were observed for hearing loss category (Fig. 1), receiver type (Fig. 3), and volume control setting (Fig. 4).

FIGURE 2

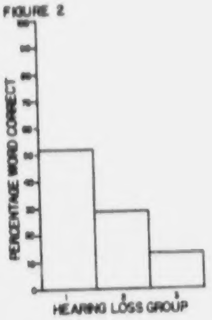


FIGURE 3

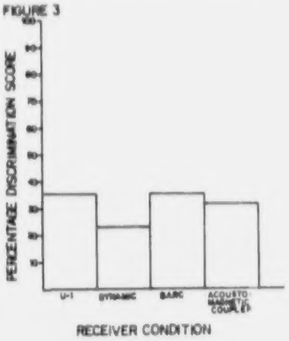
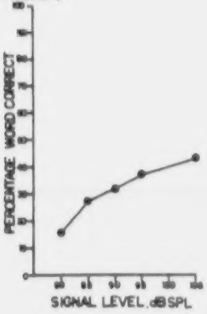


FIGURE 4



3. The data unequivocally show that use of the U-1 and BARC receivers results in identical word discrimination scores by hearing impaired subjects who use magnetic coupling between hearing aids and telephone receivers.

4. The AMC does not perform as well as the U-1 and BARC receivers. This is quite surprising when one considers that the magnetic field produced by the AMC is virtually identical to that of the U-1 or BARC. It is, however, conceivable that the air conducted acoustic radiation from the U-1 receiver (or BARC) reaching the eardrum of a listener, bypassing the hearing aid and earmold, is an important secondary acoustic transmission path. This would be especially the case at the higher signal levels. The rubber cup of the AMC may efficiently attenuate this secondary airborne transmission path thus reducing the signal level at the listener's ear.

SUMMARY

1. The ANOVA results clearly indicate no advantage under any experimental condition or hearing loss category for any particular hearing aid used in the study. These findings may be confounded to a certain extent by the fact that subjects were encouraged to hold the telephone receiver in the position that maximized signal audibility. This might have "neutralized" any relative effects for telecoil location because realistic (two-way) communication would not permit some of the receiver placements observed.

2. There is no overall difference in performance between the U-1 and the BARC receivers. There are statistically significant differences between the U-1/BARC performance and the Dynamic receiver and the Acousto-Magnetic coupler performance. The poor performance overall of the Dynamic receiver was not unexpected because the magnetic flux created by this receiver is significantly lower (≈ 20 dB) than the U-1 or BARC.

UNDERSTANDING SPEECH THROUGH THE SKIN: THE TACTILE VOCODER

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ABSTRACT - The tactile vocoder is a device, designed at Queen's that presents speech and environmental sounds as vibrational patterns to the skin of the profoundly deaf. Using only the information from the tactile vocoder, subjects have learned to identify words and environmental sounds. The device also supplies information that eliminates much of the confusion inherent in lipreading.

For the past ten years at Queen's we have been designing and evaluating tactile vocoder for the profoundly deaf (Richardson & Frost, 1977; Scilley, 1980; Brooks & Frost, 1983). The goal of this research is to provide the profoundly deaf with a wearable tactile vocoder that will aid in identification of speech and environmental sounds, and provide feedback for improvement of vocalizations.

In the tactile vocoder, auditory information enters the system through a microphone. The information is then filtered by 16, 1/3 octave bandpass filters whose centre frequencies range from 200-8000 Hz. After logarithmic amplification, the outputs are fed to an array of solenoids that are worn in a linear array mounted on the forearm. A single filter channel activates a single solenoid. Speech and sounds in the environment are felt as patterns of vibration on the skin. Presently five portable systems have been built.

A) Experiments on Normal Subjects.

Initially, normal hearing subjects, who were artificially deafened, were trained to identify "live spoken" English words. The most advanced subject learned to identify 250 words, in 80.5 hours, using only the information received through the tactile vocoder. The performance of this experienced subject was then examined in more detail in the following experiments.

1) Identification of open set novel words through the tactile vocoder alone.

This experiment investigated the subject's ability to identify common words in the English language that she had not necessarily had tactual experience with previously. The subject was not shown the possible set of words the stimulus words were drawn from. One thousand different words were presented to the subject. During the experiment the reader would say one of the novel words and the subject would try and identify the word using only information obtained through the vocoder: lipreading was not allowed. The following words are examples of some of the 89 words that were correctly identified by the subject using only information obtained through the tactile vocoder.

trust
instead
strange
matter
above
past

tried
care
function
interested
married
finished

son
shall
student
allowed
discussion
bird

Thus, a subject who had less than 100 hours experience learning 250 words through the tactile vocoder, could use this knowledge to correctly identify many novel words; words she had never had experience with previously on the tactile vocoder.

The mistakes the subject made were very interesting and indicate that a tremendous amount of information is provided through the device. For approximately 300 words, the stimulus and response words differed by only one or two phonemes as the following examples demonstrate:

STIMULUS	RESPONSE	STIMULUS	RESPONSE
SHORT	SHIRT	MATTER	WATER
FALSE	FACE	HORSE	HOUSE
TASK	CASK	CHECK	CHICK
STRIVE	STOVE	COUNCIL	CANCER
APPLIED	APPLAUD	FATHER	FURTHER
FRAME	FROM	POISONOUS	BUSINESS
AFFORD	AFRAID	MACHINE	MISSION

When the responses were analyzed at the phonemic level, it was determined that 36.7% of the phonemes were correctly identified. This is very impressive performance when the type and amount of training the subject received is considered.

2) Identification Open Set Sentences:

The next type of stimuli that were

used were open set sentences. Again, the subject was not aware of the possible sentences that would be presented. A response by the subject was scored correct if the sentence was repeated word for word correctly after it was spoken by the reader.

The subject was tested under two conditions: 1) Lipreading, (L) and 2) Lipreading plus the tactile vocoder, (L+TV). One thousand different sentences were presented in each condition. In the L condition the subject repeated 30.6% of the sentences correctly. In the L+TV condition 58.4% of the sentences were repeated verbatim. Thus performance improved by 27.8% when information from the vocoder was provided. Samples of some of the sentences the subject repeated correctly, are shown below.

HE SLIPPED AND FELL AS HE CROSSED THE ROAD.
I FORGOT TO WIND THE CLOCK LAST NIGHT.
MY ROOM IS AT THE END OF THE HALL.
HE SCORED FIVE POINTS FOR HIS TEAM.
ARE SUMMERS OFTEN THIS WARM?

The data can also be analyzed by determining the number of words within the sentences that were correctly identified. In the L condition, 57.8% of the words were correctly identified, whereas in the L+TV condition 79.6% of the words were correct. When information from the tactile vocoder was added to lipreading 21.8% more words were correctly identified.

These experiments show that a subject, with 80 hours of previous experience learning words, can correctly identify words that she had never had tactual experience with previously. When lipreading and contextual information were added the subject could identify 79.6% of the words in sentences.

B) Experiments on Profoundly Deaf Subjects.

In the experiments described below, the subjects' hearing aids were removed and they wore earplugs, and headphones carrying white noise, to ensure that they were not receiving auditory information. When necessary, a baffle was placed between the subject and the reader so no information could be obtained from lipreading or body movements. The subjects were trained on the tactile vocoder for daily half hour sessions.

1) Word Identification

The first experiment examined the ability of two profoundly deaf teenagers to identify words through the tactile vocoder. In the initial session three words were presented on a board that was visible to both the reader and the subject. After training with these words the subject was given a test containing 50 random presentations of the stimulus words. If criterion of 80% correct was reached, new words were added to the vocabulary. This procedure continued with the vocabulary expanding from 3 to 5, 8, 10, 12, 15 ... words until both subjects had reached criterion on the 50 word vocabulary. Subject 1 learned the 50-words in 25 hours and Subject 2 acquired the vocabulary in 21 hours. Thus, word learning is possible with prelingually profoundly deaf teenagers as well as normal subjects.

2) The Tactile Vocoder as an Aid to Lipreading:

Lipreading is a very difficult task because the 40 phonemes in English are reduced to about five mouth movements in conversational speech. For example /p, b, m/ sound different, but look identical to the lipreader. It has been estimated that less than 25% of the speech information available to the ears is possible through the eyes. A profoundly deaf subject was tested to examine whether the tactile vocoder supplemented lipreading, by supplying such uses as voicing, nasality and frication.

First, the subject was tested using lipreading only on identification of 'bet-pet-met'. As the following table shows, the words were correctly identified 40% of the time. The subject was then trained for about 10 minutes to discriminate the words using only the tactile vocoder. The identification score increased dramatically to 87% correct. This same procedure was followed for other groups of sounds that look identical to the lipreader: /t, d, n, l/, /s, z/, /ʃ, tʃ, dʒ/, /k, g, ŋ/. The average test score jumped from 39% in the lipreading alone condition to an impressive 88% when information was obtained only from the tactile vocoder. Thus the device eliminated much of the confusion inherent in lipreading by supplying the subject with complementary information that helped him discriminate within mouth movement groups.

Stimulus Words	Phoneme	Lipreading	Tactile Vocoder
pet,bet,met	p,b,m	40%	87%
tot,dot,not,lot	t,d,n,l	53%	82%
sue, zoo	s,z	40%	92%
ship,chip,jip	ʃ,tʃ,dʒ	44%	93%
wick,wig,wing	k,g,ŋ	20%	86%

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SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 25

TECHNOLOGY FOR THE VISUALLY HANDICAPPED/

TECHNOLOGIE POUR LES PERSONNES ATTEINTES DE TROUBLES VISUELS

HUMAN FACTORS CONSIDERATIONS IN THE DEVELOPMENT OF LARGE PRINT DISPLAY FOR THE VISUALLY IMPAIRED COMPUTER USER

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ABSTRACT - This researcher is designing an "intelligent" large print display for the visually impaired person. This paper is the result of preliminary human factors considerations of the display-user interface and semi-structured interview with a potential user of the yet-to-be-tested display system.

RÉSUMÉ - L'auteur de cette communication travaille à la conception d'un affichage "intelligent" imprimant en gros caractères, et destiné aux personnes ayant des troubles visuels. Il y décrit les résultats de l'examen préliminaire des facteurs d'adaptation humains de l'interface affichage-utilisateur, et d'une entrevue avec un utilisateur éventuel de ce système d'affichage, qui en est encore à l'étape des pré-essais.

INTRODUCTION

In the opinion of this writer it is time to realistically look at what needs to be done to help the visually impaired population keep pace with the technology which is rapidly being embraced by American businesses and homes during this decade. It's time to foresee the jobs which this decade has and will continue to offer those who have adapted and will continue to adapt themselves to these newly embraced technologies. This is the decade of the computer. During the next four years it has been predicted that the number of computers in the home will increase from 3 per cent to 40 per cent, and that one would be hard pressed to find an American business office which was not computerized. The full impact of this dramatic projected proliferation of technology on the disabled person is inestimable. However, it is quite easily foreseen that the new technologies will profoundly affect both the quality of life and the type of education available to disabled persons. In light of this trend this author feels that it is time to seriously examine the questions involved in how computer displays can be best formatted to provide visually impaired persons with the optimal machine-to-man interface. The task of developing this display is not trivial by any means and will require analysis of the tasks which the computer user of this decade will be performing as well as the individual needs of the user. Complete development of an optimal display will take time and a number of trials and evaluations of proposed prototypes.

In the following paper, the author has taken only the first step in this development process: he has taken an initial hard look at the type of computer display which the visually impaired computer user will require in order to work and function effectively in this computer decade.

It is the author's intent to convey the complex nature of the above chosen task of considering all the human factors involved in the design of a truly optimal computer display for visually impaired persons. In fact, the main purpose of this paper is to illustrate a few of the many considerations essential for the completion of this task to the satisfaction and benefit of the disabled persons in question. To this date, very little work has been done in this field to identify the essential variables and possible design factors, and nothing has been done to implement what little actually is known or may properly be inferred from other studies. From the point of view of this writer, it is very clear that unless a real emphasis is placed on completing the above described tasks, computer displays for disabled persons will remain as primitive and awkward devices and that the employability and quality of life of the disabled the consequences.

INITIAL APPROACH

This author acknowledges that large print displays have already been developed and implemented for some computers. This paper will not attempt to evaluate these existing applications of large print computer displays, but will restrict itself to the considerations with which this researcher is concerned in developing an optimal human factors model of a large print "intelligent" display. That is, a display which will adapt itself to the specific needs of the user and to the type of programming, word processing, etc. being performed by that user with his computer.

The first step taken by this author toward development of an optimal display was to conduct informal discussions with a visually impaired computer user who has been using an Apple II computer for four years to both conduct business and write professional programs. During these discussions, as the author questioned the perceptions of this user with respect to a large print display, it became apparent that what was needed was more than just bigger print. Depending upon the type of sight impairment, (visual acuity, visual fields, and correction if any, etc.) the optimal size and color of the print seemed to be quite variable, which indicated to this writer that these things should be user adjustable or at least be able to be selected according to the user's own preferences.

The most optimal and intelligent format for displaying computer data was not clear from initial discussions with the visually impaired computer user. It was initially suggested that the large print screen simply be a magnified version of the existing screen. However, upon further reflection concerned with specific tasks which the user must perform, it was pointed out that a magnified screen may not always contain certain important pieces of information vital to performing the required task. Because of this the user would then have to move the magnified screen window around looking for the needed information each time it was required, instead of just glancing over at it as a sighted person would normally do. With this problem in mind, it was suggested that the screen contain only one line of text, one point of which the user was to focus on as he controlled the flow of text past that point. By this means the user would be saved the time of looking back for the beginning of each line as he read through the text. This format and method of text control was considered to be an efficient means of reading sequential text, but not a good method for reading columnized data. In the latter case it was suggested that an "n X n" matrix of user chosen size be provided as an option with the data again placed about a fixed focal point. Also, it was recommended that the user should have the ability to scan data either vertically or horizontally past this focus point. The capability of locating column and row headings on the screen at all times was felt to be of great aid. It was also suggested that joystick control of the above mentioned horizontal/vertical scanning function would be a valuable feature.

The use of the Musical Language in conjunction with the large display was offered as a possible enhancement. It was felt that by providing a second channel of sensory input the Musical Language could be used as a quick means of verifying the visual image, and that this verification aspect of the Musical Language would enable the practiced user to attain significant increases in reading speed over using large print alone.

Opinions concerning the amount of information which should be displayed on the screen also varied with the particular application. A programmer might be concerned with being able to see an entire line of a program at once, or at least knowing what line number he was currently looking at without having to scan back to the beginning of the line to see it. Programmers who program in COBOL, Pascal, and other structured languages might be concerned with being able to easily see the indentations from line to line. It was agreed that one possible solution to this problem would be to put the beginning of the program line being scanned in a fixed position just above the scanning point so that the line number and beginning of the line could be referenced at any time. It was also strongly suggested that a fixed display at the bottom right hand corner of the screen which gave the position number of the focal character would be essential when programming with a structured language like COBOL or Pascal since these are position dependent languages. In addition, it was agreed that it would be convenient to have the start of the next program line at a fixed location just below the scanning point for reference purposes.

Also presented was the fact that persons using word processors would need to have an easy method of lining up tabular data and setting margin widths correctly and easily. The suggestion offered here was to have the column and row headings placed on the screen in fixed positions just above and just to the left respectively of the particular column and row which were being typed or scanned.

There were also a number of other personal considerations discussed which dealt with the ease of use of a large print computer display which were beyond the scope of this research. However, it was apparent that the points listed above were those which were of major concern to the visually impaired computer user questioned. From the above suggestions it is also apparent that the most optimal large print display would either have to be one which was custom designed for the particular user, or one which would be very flexible and easily formatted by the user according to his preferences and specific uses. The above are not impossible suggestions to design for, but they will require some time and effort to implement. While this will be done at an additional initial expense, it should be noted that with increasing standardization among computers and the increasing power and size of computer stations the long run cost of implementing the above features will be minimal, since the implementation of the large print display will eventually be possible to accomplish in software alone.

IMPACT

The intent and potential impact of these considerations was to provide a means by which a well designed large print display could be evaluated for use. At the present time there is no standard by which a large print system may be evaluated with respect to its usefulness to the user or with respect to its position within a spectrum of possible large print displays. The results of this study will also be used in the development and evaluation of the Video Monitor and Emulator Display (VMED) which is the subject of another paper by Gary W. Kelly and David A. Ross.

In all cases, the above considerations were basically concerned with those possibilities which could be implemented in a practical way using current technology. It is the author's intent to implement a prototype incorporating all of the options mentioned above along with any others that seem valid and reasonable. This is being done on an Apple II+ for reasons of convenience to the author. The comments of the users of this prototype will then become the topic of a forthcoming paper, and, even more importantly, will be used to aid in the design and construction of a well designed and marketable large print computer display for the visually impaired population.

The ultimate impact and result of these considerations and continued prototype development will be to provide a better means of evaluating and selecting the proper computer display equipment for the particular visually impaired person's needs, providing a more optimal work situation for this person and an opportunity for him to make more efficient use of his abilities.

HUMAN FACTORS CONSIDERATIONS IN THE DESIGN OF EQUIPMENT FOR GUIDE DOGS

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ABSTRACT - This paper summarizes the human factors considerations in the design of a new harness for guide dogs used by both blind and visually impaired persons. The goal of this design project has been to develop a harness made from advanced materials technology.

RÉSUMÉ - Ici, on résume les facteurs d'adaptation humains dont on a tenu compte dans la conception d'un nouveau harnais pour chiens-guides. L'objectif de ce projet est d'élaborer un harnais qui recourt aux plus récentes technologies des matériaux.

INTRODUCTION

The number of functionally blind persons having a visually impairment severe enough to substantially limit their normal interaction in society is estimated to be approximately two million in the United States alone. These persons often need assistance in mobility, which is certainly a prerequisite for independent living.

The Veterans Administration classifies devices for the visually impaired person as one of its top three priorities. In an effort to advance the state of the art in systems to assist the visually impaired traveler in mobility, a design project was begun at the Atlanta Veterans Administration Medical Center to examine the equipment used by guide dogs for the blind.

The fundamental question asked was: can equipment used by more than 12,000 blind travelers on their guide dogs be improved to provide a more serviceable system for independent travel? To this end research was begun. The first step was to contact guide dog schools and persons utilizing guide dogs.

There are eight guide dog schools in the United States. They graduate a combined total of about 1650 dogs a year. When a person goes to one of these schools, they generally stay in dormitories on the campus for three to four weeks. Upon graduation, the student and the new dog leave the campus with two vital pieces of equipment: a leash and a harness.

The leash is a simple and practical piece of equipment and similar leashes have been made and recommended for pets by trainers for some years. However, the harness worn by guide dogs is unique and is not as readily available as the leash. The harness is a special tool which enables the dog to communicate messages to the disabled person, as well as, enables the person to communicate with the dog. For those not familiar with the guide dog harness a description is provided in the appendix.

Upon contacting the eight guide dog schools the authors determined that a majority were indeed very interested in the development of new equipment that would lower costs, provide greater esthetic value, be more easily attached to the dog, and provide better interaction between man and dog.

Several schools indicated a desire to avoid the use of leather and metal for a variety of reasons, usually cost and care problems. Leather costs and fabrication costs are comparatively high on the existing harness.

In addition to the letters to the major guide dog schools (all of which answered), interviews with two guide dog users were conducted. The information obtained was helpful in determining design criteria for a possible new harness and leash.

The existing leash was only a problem in that it utilized leather with the consequent problems of leather equipment. A recommended change was to choose an alternative material that would have qualities superior to leather in terms of wea ability to withstand moisture, color, an stretching. The solution appeared to be one materials substitution.

The harness however, had quite a few more in depth comments that have led to several design changes. These are outlined in a table below.

TABLE 1.1 Existing equipment characteristics and recommendations.

CHARACTERISTIC:

(PRESENT)	(NEW)
LEATHER	NYLON
Absorbs moisture	None
Has an odor when wet	No odor
Stretches badly	None
Cracks with age	None
Discolors with age	No discoloration
Difficult to clean	Easy to clean
Limited color selection	Wide selection
Heavy in weight	Light weight
Perceived to be uncomfortable	Foreseen as comfortable
METAL (buckles)	SCOTCH-MATE (velcro)
Difficult to use	?
Heavy in weight	Light weight
Sets off alarms in airports	Non-metallic
Not fully adjustable	Fully adjustable
METAL HANDLE	ACRYLIC HANDLE
Heavy	Light

In addition, the buckles and metallic parts of a harness are perceived to be uncomfortable to the dog by others. This sometimes causes embarrassment to the guide dog user when pointed out by others. The handle of the harness is also metal, sometimes covered with leather, and design recommendations were to make this of plastic to reduce weight, improve esthetics and wear, and reduce probability of setting off metal detectors in airports.

From the above criteria presented by both guide dog users and from a study of the harness itself, design criteria was established to construct an improved guide dog harness. Table 1.1 also presents alternate materials choices and characteristics of these materials as used in a guide dog harness. It is evident that advanced materials technology can readily improve the harness and the leash.

INNOVATION

The new leash was easily designed using similar hardware with lighter weight and less bulky characteristics. Nylon strapping was substituted for the leather. This strapping was similar to that used on automobile seatbelts, only narrow in width. It comes in a variety of colors at low cost and can be sewn easily. A leash of this type was constructed that is functionally identical to the existing guide dog leash. It has had all the advantages presented in table 1.1 over leather and has indeed withstood wear and stretching very well to date.

The harness had nylon of a similar type to the leash substituted for the leather. A product similar to velcro called Scotch-Mate (available from Minnesota Mining and Manufacturing, 3-M Corp.), was used in place of buckles. This has been quite successful to date in that is is infinitely adjustable, light-weight, and very easily cleaned. It is definitely perceived as being "more humane" by others.

Nylon was chosen for the material to replace leather because it is lightweight, more comfortable, and is believed to have a longer lifetime. Washing cleans it well, it does not stretch in shape when wet, and it requires little care. Nylon strapping is less expensive than leather which lowers the production costs of the harness. Nylon strapping also comes in a large variety of colors, which increases the esthetic value of the harness. The disabled person may choose a color to match the dog's coat. It is even possible for the disabled person to own different colored harnesses which they may interchange to match their wardrobe. Nylon has some distinct advantages over leather which is the reason it was chosen for this design project.

It is important to understand the two-way nature of man-dog communication through the harness handle. The handle is the mechanism by which the visually impaired traveler senses the direction, behavior, confidence, and gait of the dog. It is quite easy to tell which way the dog is looking, whether or not he is sniffing, limping, or if unsure of his path. The dog senses the gait of the owner, intentions, and confidence. The initial harness handles were made from both acrylic (clear), and polycarbonate rod (smoked).

Prototype models of the leash, harness, and harness handle were made and persons using guide dogs were asked for additional input to the design criteria. The simplicity, practicality and esthetics were rated highly by the users.

The negative attributes appear to be that the leash has a greater tendency to "tangle" than the leather equivalent but this can be rectified by using a slightly stiffer (thicker) and wider nylon webbing. The same feature is true of the harness, and can quite probably be solved in a similar manner.

The new harness handle excelled as a communication link since there appeared to be less "damping" of the signals. However, preliminary harness handles have not been as durable as necessary. Several have broken upon impact, and a satisfactory method for making them at the lowest cost is still under investigation. Nylon and delrin are alternate possibilities which have excellent characteristics but not the esthetics of the smoked or clear plastics. A new compound from 3-M promises to be satisfactory from information to date and tests by users over the months to come will demonstrate whether or not this is satisfactory.

CONCLUSIONS

Advanced materials technology does indeed offer considerable improvement in the design of equipment for guide dogs in almost all areas. The evaluation of such technology is primarily a human factors evaluation and the final outcome will be determined in the field. Plans are already formulated for the cooperative testing of the VA Guide Dog Harness in several of the schools who have expressed a desire to assist in the field evaluation.

APPENDIX

The general design used for most guide dog harnesses is as follows: a leather body strap which circles the dog's body behind the front legs, a leather breast strap which goes across the dog's chest, and a rigid metal handle attached to the breast strap. The body strap keeps the harness snug on the dog. The breast strap is the part of the harness the dog pulls on while guiding. The handle is the means by which communication between the dog and the owner takes place. When putting the harness on, it is placed over the dog's head and is buckled like a belt, at the body strap. The type of harnesses given to guide dogs and their owners vary: each school has their own specific design. Some schools add an additional leather strap, called a martingale, that is attached to the breast strap and runs between the dogs front legs. The martingale causes the harness to fit much tighter on the dog which makes his movements and signals much clearer to the disabled person. Some of the schools cover the metal handles with leather for esthetic and comfort purposes. Some include reflective material on the harnesses, for safety in night travel. Other varying ideas are used for guide dog harnesses, but the basic structure is the same.

RESEARCH FOR THE VISUALLY IMPAIRED COMPUTER USER

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ABSTRACT - Following a needs assessment for ten visually impaired trainees, two areas of research were conducted: assessment of readability of varying character sizes for the partially-sighted, and adaptations of the Kaypro II and PET microcomputers. As a result of this study, these students received business-oriented computer skills.

RÉSUMÉ - A la suite de l'évaluation des besoins de dix étudiants atteints de cécité partielle, deux domaines de recherche ont été explorés: l'évaluation de la lisibilité de différents caractères de taille variable pour des personnes ayant une vision partielle et l'adaptation des micro-ordinateurs Kaypro II et PET. A la suite de cette étude, les étudiants ont reçu une formation dans le domaine des ordinateurs qui leur permet de travailler dans le secteur des affaires.

NEEDS ASSESSMENT

The Nominal Group Technique (NCT) was used to establish criteria for design of electronic aids for the handicapped client (Schubert and Schweitzer, August, 1982). The following statement was a point of departure:

> "Given ten visually-imparied trainees with a goal of learning basic business skills with microcomputers, what perceptual problems does our technology (ies) need to solve?"

Table one displays the result of the NGT with the "top five" problems selected.

CHARACTER SIZE READABILITY EVALUATION

The partially sighted students were evaluated to determine the optimal size of character that each student could effectively read on the display screen. A Radio Shack Model III was used with a 13" diagonal screen, in the Microsoft, Basic language. Six different sizes of characters were presented to the students. Size ranged between 3.75 mm wide by 5.75 mm high and 92.5 mm wide and 105 mm high. Each character was displayed on the screen for several seconds. Students knew a standard typewriter (QWERTY) keyboard and could type the character they perceived on the screen. After all 43 characters had been presented, the program printed a table of the letter size and percent correct with a graph of the results. The name and number correct by each character size were stored on a disk file.

One promising result was that by increasing the size of a character to only slightly larger than normal for the Model III, the percent recognition of the characters presented increased sharply.

ADAPTING THE VOTRAX SPEECH SYNTHESIZER TO KAYPRO II

Another objective was to adapt the computers to meet the special needs of each student. One step was to use the Votrax speech synthesizer with the Kaypro II business computer. Instead of reading from the screen, the non-sighted had the contents "read" to them by the Votrax. In order to cause the Votrax to state the contents of the screen, the operating system was changed so that the output to the screen was also directed to the speech unit. Kaypro II uses a more advanced CP/M operating system than either the PET or TRS-80. The CP/M supports "input/output redirection" which means that these devices can easily be changed. The computer does not have a special port, however there is a port for the printer and an RS-232C port. The Votrax likewise has an RS-232C port and this was connected to the Computer.

Some technical problems did occur with this system. First, the Votrax does not perfectly promounce certain words. Also, the unit ignores punctuation marks which are important in programming BASIC. Other shortcomings were discovered. The Votrax could only speak words and sentences, although the user may wish the individual letters repeated. This was somewhat alleviated by the "spelling checker" program.

ADAPTING THE VOTRAX FOR PET

Vocalization for the PET was not as simple as the Kaypro, and involved the insertion of "patches" in the system operating program. A jump or patch needed to be made to a position in the memory structure with enough room; i.e.; the RAM sector. Another option to allow start-up was to use two patches: one to RAM and one to ROM. When turned on, the first patch encountered would be in ROM. This patch would cause the operating system to write into RAM. Another program is added to the RAM which causes the temporarily stored information to be sent through the RS232C port to the Votrax.

A PET 2001 with RS-232 capability and modified chips with the Votrax are needed for this system to operate. The 4K ROM chips from the PET were replaced with EPROM chips. The performance of the system was limited, and a programming concern is a mismatch between the baud rate of the system components.

OVERVIEW OF TRAINING

In business applications, basically three types of programs are used: word processors, database managers and electronic spreadsheets. The visually impaired students were taught the fundamentals of the CP/M operating system in addition to the basic operations of business applications software. For this purpose, "PERFECT WRITER" and "PERFECT SPELLER" were used.

Software programs were used interactively with the trainees to learn basic commands needed to use the programs in the job setting. Students spent several hours each day learning eight lessons. All students completed all 8 lessons. Electronic spreadsheet for calculations and basic accounting were also presented, with all trainees demonstrating knowledge of the purpose and concepts of the technique. Students expressed an interest in additional training with this software.

For those students who entered the program with some programming skills, and introduction to PASCAL language was presented. Following training, most students indicated a preference for this language over BASIC.

CONCLUSIONS

Authors and students consider the program, in general, to be a success. Adaptations of the computers did not resolve all technical problems associated with achieving independence for all visually-impaired trainees. Progress was made in utilizing speech systhesizers as an aid. The addition of a Braille printer is recommended for (trainees who are trained in Braille) for writing text and programs. At the time of publication, half of the class had found gainful employment.

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Table 1 Results of Nominal Group Technique

Item #	Statement	Rank 1st	Rank 2nd	Weight
1.	Need to Assess Seating and Bracing of the client			
2.	Needs Accurate "picture" of the screen(client need)			
3.	Need instantaneous Audio Feedback from the Keyboard (by-Letter)			
4.	Client cannot See.			
5.	Assess Individual Need for Feedback from the Computer.	7 pts #1		
6.	Need Dependable, Reliable, Audio Feedback for Longer Text.	8 pts tie#3	6 pts #5	80
7.	Can Client Interact with the Keyboard?			
8.	Keyboard is too Sensitive			
9.	Tactile Feedback From the Screen	4pts tie#5	16pts. #2	180
10.	Random-access, Indexed-by-Line (Select by Indexed System, not from visual information on screen)	8pts tie#3	8pts #4	70
11.	Need more Intelligible Voice Synthesis.	1 pt.	1 pt.	
12.	Need more Computer Hardware.	2 pts	2 pts.	
13.	What Size Image Can Some Clients See?	3 pts		
14.	Need for Standardized Keyboard.			
15.	Need Keyboard "stick-on" with either Letters or Dots with Tacile Feedback.			
16.	Need Format Feedback (ie; Word Processing Output)			
17.	Assess Personal Needs of Individual Clients.	15pts #2		
18.	Group Disabilities-Abilities for Technical Support or Solution.			
19.	Problems with Access to Controls (other than Keyboard)?			
20.	Need More Individual Attention. (during operation		4pts	10
21.	Hard Copy Output that Client Can Read.	4pts. tie#5	4pts.	10
22.	Need for "Readable" Source Documents.	3pts.		
23.	Need for Standards for Progress in Program.	3pts.	1 pt.	
24.	Need for Positive Client Feedback About Learning			
25.	Need to Assess Psycho-social Factors(fear, anxiety	2pts.		
26.	Need for Hands-on Practice Beyond Initial Instruction			
27.	Feed Back Identifier for Diskette and Drives.			
28.	Need for Knowledge of What Equipment is Available	5 pts tie#4		
29.	What Placement Goals Need to be Addressed?	1pt.	1 pt.	
30.	What Procedures Need Be Followed for Equipment Acquisition? (before/after training)	8pts. tie#3	9pts. tie#3	50
31.	More Structured Learning System(goals, tracking and Training Management/IEP		3pts.	
32.	Need to Focus on Typing Skills (practice etc.)			
33.	Need to Develop Programming Skills.			
34.	Need to Develop Skills in "BASIC"			
35.	Need Programming (and memory)Aids in Braille.	1pt.		
36.	Need Feedback About Cursor Position	4pts. tie#5	4pts.	10
37.	Assessment of Individual Clients for Measuring: Hearing, Seeing and Feeling Feedback Efficiency (of each mode of perception) Note: during 2nd ranking, this item was collapsed w #17.	#17	25pts. #1	190

JOB PLACEMENT AND THE PERSON WITH LOW VISION

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ABSTRACT - Through case presentations the low vision specialist demonstrates how rehabilitation engineering techniques can enhance the placement of the legally blind/visually impaired persons.

RÉSUMÉ - Par le biais de présentations de cas, le spécialiste des troubles de la vision montre comment la technologie de la rééducation fonctionnelle peut améliorer le placement des personnes légalement aveugles ou souffrant de troubles visuels.

In the United States there are approximately 500,000 legally blind individuals.(1) Although statistics are poor, it is estimated that 77% of those have some form of measurable vision.(2) Through the use of specialized lenses, proper lighting or special techniques, low vision services may enable an individual to utilize residual vision successfully. The aim is to magnify to gain a large retinal image which may allow unaffected areas of the eye to perceive it. The image will not be clearer, just larger.

Individuals who have received successful low vision services may have low vision aids (magnifiers) that will allow them to perform personal tasks, near tasks such as reading and writing, or distance tasks such as reading a blackboard or street signs. These personal aids can be useful for some vocational tasks but may be of limited use in others. In general, low vision aids are very task specific.

The low vision specialist's services are required when:
1) The individual employed in a situation is having difficulty performing one or more of the required tasks.
2) An individual is seeking employment from a specific employer and needs assistance in determining how required tasks can be performed.
3) Specific low vision aids need to be evaluated for defined tasks at the work site.
Once the low vision specialist is enlisted, three steps are taken to help solve the problem:
1) Client Assessment
2) Specific Task Analysis
3) Modifications

A Client Assessment is made to gain information about the client's potentials and limitations as related to vocational endeavors. To accomplish this, information is gathered on the background of the eye condition, present vocational skills, manipulative functioning, educational and vocational histories.

An on-site vision assessment is made to determine the amount of residual vision, how the individual uses that vision, the potential of current low vision aids, and the possibility of improving the use of the vision with aids, equipment, or techniques.

The following areas are assessed:
Visual Status: The nature and history of the vision impairment; short-term changes and fluctuations of the vision; history of low vision services; measure of visual acuities.

Near Tasks: Reading abilities with and without aids; print size (regular, large print), duration -- short-term (labels, mail) and long-term (books, magazines); near object detection and identification ability; color identification; eye-hand coordination.

Distance Tasks: Travel ability using vision; object detection and identification at a distance; ability to read signs, recognize people, distinguish traffic lights, avoid obstacles; use of distance low vision aids.

Illumination: Determination of the effect of various lighting conditions (artificial and natural) on visual performance; best light for near tasks; methods to eliminate glare.

A Specific Task Analysis is made at the job site. A job usually consists of a collection of tasks constituting the total work assignment, and each of these tasks consists of a distinct activity. The individual components of the job must be analyzed to determine how the visually impaired individual will accomplish them. Through observation and discussion, determination will be made as to (1) the worker functions, 2) the expected output, 3) the instruments and devices, and (4) the worker traits desirable for the position. Once each task is defined, it can be determined which of these tasks will present difficulties. (3)

Modification

When the visual capacities and the visual potential of the individual are known and specific task difficulties are determined, then investigation of possible solutions can be explored.

To be performed effectively, each visual task usually requires a certain visual acuity. For example, to be able to read the display of a CRT may require a magnification of 4X for an individual with an acuity of 20/200 (6/60). A specific working distance will determine the type of low vision aid used to achieve the required magnification.

Low Vision Aids

In placing low vision clients, the majority of magnification aids used can be divided into three categories. (4)

1. Convex Lenses

Single lenses systems of various powers ranging from 8 diopter to 80 diopter (2x to 20x relative magnification). The focal distance of the lens is determined by dividing its diopter value into 100 cm. Convex lenses are available in various types with the following characteristics:

Spectacle lens
--working distance is abnormally short
--both hands are free
--largest field of view of any optical aid

Hand and Stand Magnifiers
--Can be used at a greater distance from the eye
--Reduced field of view
--Both hands are not free

Convex lenses are good personal aids for many reading and short-term identification tasks.

2. Telescopic Loupe (Telemicroscopes)

In situations where a greater working distance is needed than is obtainable from convex lenses, a telescopic loupe may prove useful. Telescopic aids of various magnification are used with auxiliary lenses to focus the system at a specific working distance, determined by the focal distance of the auxiliary lens. These aids can be handheld, mounted on a stand or mounted in spectacles. A few systems such as the bioptic, have been developed that incorporate a small, light telescope that can be easily inserted in spectacles which allow the user to attach a lens so that a magnified image at a desired distance can be obtained. The major disadvantage of this system is that there is a narrow field of view through the system and the depth of field is very shallow.

3. CCTV Magnifiers

Video magnification systems have been found to be a very useful low vision aids. A video camera with a zoom lens is mounted to display onto a television monitor material that is placed on a movable platform. These commercially available systems allow variable magnification from 4X to 40X and have variable contrast, including a negative image (white letters on black background). These systems can usually allow an individual to read printed documents or view objects at a comfortable distance and at a magnification and contrast level that reduce strain and fatigue. The system can also be used for writing tasks, or with the camera aimed into a typewriter it can be used to review typed material and make corrections. Although a sophisticated system, it has been found to be extremely useful to individuals who have a great visual acuity loss and whose jobs demand a great deal of paper work.

Case Presentations

The following job placement examples will better illustrate the techniques employed and the equipment used to overcome problem areas in the job duties of a visually impaired employee.

Case 1

Client

Mrs. JD is a 50-year-old woman whose vision impairment is due to optic nerve atrophy of an unknown cause, with a central loss of vision which reduces her visual acuity to 20/800 (6/240). Mrs.

RADIO-DISTRIBUTED DIGITAL DAILY
NEWSPAPER FOR THE BLIND

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ABSTRACT - Computer stored text, now a commonplace in newspaper production, is used to create an unabridged digital newspaper for the blind, including all news and advertisements as in a regular newspaper. It is the first true electronic newspaper what so ever. It is distributed via FM-radio and provided with flexible read-and-search structure.

RÉSUMÉ - La mise d'un texte en mémoire, chose courante aujourd'hui dans la production de journaux, est utilisé pour créer à l'intention des aveugles un journal numérique complet qui renferme toutes les nouvelles et annonces qu'on trouve dans un journal ordinaire. Il s'agit du premier vrai journal électronique. Il est diffusé par radio FM et a une structure souple de lecture et recherche.

With this new method an unabridged version of the daily newspaper is delivered to blind subscribers. It is in principle identical with its paper-printed original. An unshortened daily has always been an important issue for blind people. Now it is possible thanks to computerized phototypesetting techniques. The graphic material and parts of the text not processed in the printing-house´s computer are the only items omitted from the blind-paper in comparison with the regular paper.

Another important factor is not to delay the delivery, so that the blind really get the news and not yesterdays news. This blind-daily is distributed via the FM-radio station and the blind reader gets his copy at night, several hours before the sighted subscriber. The number of subscribers is not limited because of technical reasons (as compared with the telephone delivery [1]) and the system can easily be developed to include more newspapers.

The text is presented on a tactile display or can be listened to from a speech synthesizer. It is possible to move rapidly between the different parts in the text thanks to the search procedure developed for the system. This is an important point - the blind reader should be able to read and search in the newspaper with a maximum flexibility comparable to that of a sighted reader.

The only existing competitors, to this digital based daily for the blind, are newspapers acoustically recorded on audio-casettes [2]. These are only short extracts (5-10%) of the regular newspaper. 12 hours recording is needed for a full-sized newspaper and this makes search-routines practically impossible.

Read and search structure

Both tactile terminals and speech synthesizers have been used as presentation media for this daily paper for the blind. On a tactile terminal a line of 20-40 characters can be displayed. A new line appears after pressing the new-line button. This is basic reading technique. With no search possibilities the blind could only follow the text line by line. This would be equivalent to cover-to-cover reading for a sighted reader. This is not what we seeing people do. We usually choose a page, look for interesting head-lines and then continue to read the text that follows. In this daily for the blind, the search-and-read procedure is basically the same.

Read and search flexibility must be strongly emphasized. The flexibility is possible only if the text stored in the printing-house computer is well structured. One has to remember that this structure was not meant to suit the needs of a daily newspaper for the blind. Four conditions for maximum flexibility have to be specified.

1. Computer-stored text should be page- or class-oriented, i.e. with the text divided into front-page news, editorial, domestic news, sports etc.

2. Computer-stored text has to be divided in separate, detectable articles as in regular newspapers.

3. Head-lines, abstracts, captions, subtitles etc. within the articles must be marked.

4. There has to be a possibility to distinguish important news, and to build up a rankinglist within a page or a class, with the most important news at the top of the list.

The first two points are crucial, if a readable newspaper is to be obtained. It not fulfilled the computer stored newspaper is nothing more than a great homogeneous text aggregate.

The first blind converted newspaper is Göteborgs-Posten (G-P), a local daily with 300.000 subscribers. It is edited in Göteborg and averages 600.000 characters on 40-64 pages with a significant amount of advertisments. G-P´s computer structure includes the above four points even if all of them are not explicitly present. The text is class oriented. Page layout work is not yet computer supported. When this comes about the flexibility of newspapers for the blind and the similarity to regular newspapers will increase. Especially where points 3 and 4 are concerned.

The ordinary computer-stored G-P is divided into several hundred classes. Most of them contain advertisments. Genuine news consist of approx. 20 classes. In the G-P edition for the blind (BG-P) the classes are arranged in a four level "search-tree" with 19 items on the top (figure 1).

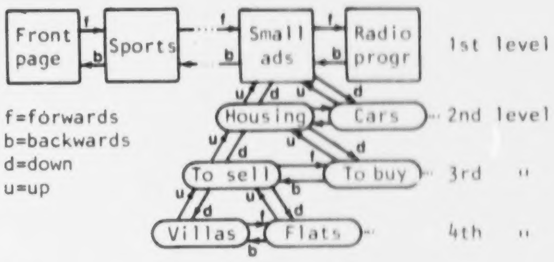

Fig.2 Search-tree.

In this 1st level the classes can be searched by name (by pressing cspo for sports, crad for radioprograms etc.). But it is not necessary. The blind reader can search even without á priori knowledge of the class-names. He can reach every class by moving forward, backward, up and down through the "search-tree" (pressing f, b, n, d respectively on the Braille-keyboard). Class searches are immediate. The reader can also step one article forwards or backwards, search for words within a class, mark a place he thinks he would like to read again.

Transmission

After dead-line at 11.00 p.m. the newspaper is transferred from the printing-house computer to a specially designed microcomputer (figure 2).

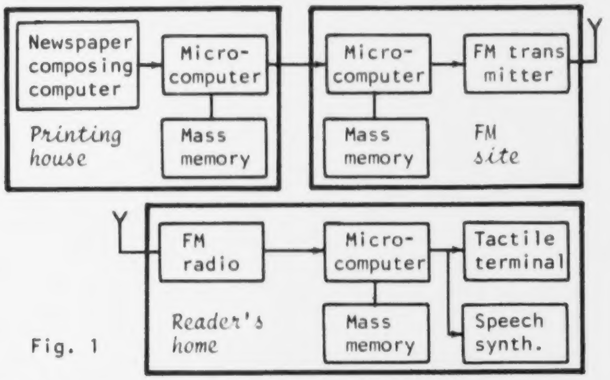

Fig. 1

This operation is initiated by the operator in G-P's computer-room and is the only manual operation in the transmission chain. The text is transferred in the same order as it appears in the standard newspaper. After storing in mass memory control characters used for phototype-setting are deleted, and information necessary for the final creation of the "search-tree" at the user-end is added. BG-P is now transmitted on cable to the FM-site (transmission-rate 12.5 kbaud) and stored there. When the ordinary radio program is completed the FM-transmitter is automatically restarted and the newspaper reaches blind readers by radio. Transmission-rate is now 64 kbaud, thus it takes approx. 90 sec. to send a newspaper of 600.000 characters.

The blind readers are equipped with a FM-radio, where the newspaper is received and a mass memory (winchester disk) where it is stored. Receiving and storing are controlled by microcomputer, which also controls reading procedures. Our experience is that FM-transmission is errorfree. To achieve this a central antenna is used. Antennas like this are standard in most houses in Sweden. The greatest distance from the FM-transmitter to the individual user has been 13 kilometers. If transmission-errors occur the reader is warned before he starts reading the newspaper.

Two different types of tactile terminals (3 Versabrailles and 2 Schönherrs) and 5 speech synthesizers are used. They operate differently, so that the newspaper-text after being received, must be adapted to a specific terminal. Even final creation of a search-structure's directory is accomplished after the FM-receiving has been completed. At the present moment (February -84) five blind users in Göteborg are attached to the system. During 1984 two more systems, operating with different dailies will be introduced in the cities of Malmö and Stockholm.

Remarks

A detailed investigation of the reactions of the blind readers will be published at the end of 1984. Some first reactions are already clear. For people born blind this was their first contact with a daily paper. They read, to a great extent, the items which were absolutely new to them, like advertisments. All five readers spent several hours every day reading their BG-P. It took some time for them to discover all the details of the search-structure, but even those who had never worked with computers before could learn.

It should be emphasized that it is relatively easy to introduce the system at different newspapers. Only changes necessary are those in dumping and filtering programs. On the other hand only practical experience will show the ability of newspapers for the blind to survive changes in the computer systems at the printing houses.

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A MICROPROCESSOR-DRIVEN OPTACON INTERFACE TO A READING AID FOR THE BLIND

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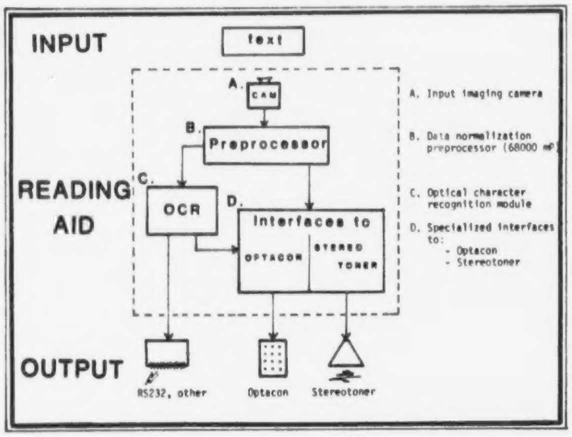
ABSTRACT - A reading aid currently under development for blind people will have, as one output option, a microprocessor-driven Optacon to display processed digitized data from a camera. The parent project and this particular component are described, and various rehabilitation applications for such project components are discussed.

RÉSUMÉ - Une aide visuelle pour les aveugles est présentement sous développement. Une des options offertes sera un écran Optacon contrôlé par microprocesseur. Cet article comprend une discussion de diverses applications ainsi qu'une description des composants de cet écran.

A VERSATILE READING AID

Overview.

Work is underway to develop a reading aid for blind and low-vision people which can be adapted to meet the needs of a wide range of disabled users. It is to be relatively compact, microprocessor-based unit with a hand-held camera, capable of capturing a variety of type sizes and fonts, and able to communicate scanned text to the user via a variety of output options. Individuals using the device can choose from among the output options to suit best their own skills, preferences, and finances.



READING AID BLOCK DIAGRAM

The reading aid comprises the following primary modules: A) the input imaging camera, B) the data normalization preprocessor, C) the optical character recognition (OCR) processor, and D) the output interfaces. Module A, the input camera, uses a solid state linear imaging chip having a sufficient resolution and number of elements to acquire text from 6 to 60 points in height (approx. 0.08 to 0.83 inches). The solid state chip features both high reliability and compactness, and provides for a large enough aperture to allow for relatively large tracking errors during hand scanning. Module B, the data normalization preprocessor, will use signal processing techniques on digitized camera data to effect image thresholding, magnification, line finding, and character finding. Packets of data containing size-normalized characters will be handed from Module B to Module C, the optical character recognizer, for computer identification. Finally, special output interface boards -- Module D -- will communicate with various display devices: output options to disabled users include an Optacon, a stereotoner, a low-vision display for generating large characters, and a speech synthesizer for voice output. If desired, the reading aid can transfer text to another computer, a mass storage device, or a printer, thus allowing the device to be integrated into a work station for both sighted and blind people in an office environment.

The Optacon output interface.

A closer look at one of the output interfaces, now operational, illustrates some of the ways in which not only the reading aid as a whole, but also the individual components, can be useful in ongoing rehabilitation research and development work. This Optacon output interface allows the reading aid's central microprocessor to generate all the signals necessary to drive the Optacon's (R1D) vibrotactile and light box displays. The interface hardware can be driven by an eight-bit or sixteen-bit microcomputer using the industry standard 'Multibus' architecture. The interface itself is treated as a memory location, and is made active by sending an output 'mode control word' consisting of the mode of operation (0 through 6) and the Optacon display width. The data from the interface can be displayed in tactile and visual Optacon format in any of the several modes until the most suitable form of display is determined. Sample modes include continuous scanning to the left or to the right, and individual character display. Development equipment relevant to this part of the project includes a 68000 microprocessor board, the Optacon hardware interface board, the Multibus chassis and power supply, the Optacon and Optacon light box, and connecting cables to drive the Optacon; there are no internal modifications to the Optacon itself.

VARIOUS OPTACON INTERFACE APPLICATIONS

This VA/NASA-developed Optacon interface will be useful in a variety of ways, both on this project and in related work currently underway at Stanford University. It can provide:

Human factors information:
Operation of the standard Optacon requires the user manually to guide the camera, adjust the magnification of the Optacon lens, detect line changes when reading text, and track the camera against drift as it traverses a line of text: these represent several distinctly challenging tasks. Since the reading aid under development will perform scaling operations in software, and will handle -- within relatively large drift tolerances -- line tracking also in software, the user's responsibilities will be lightened: he/she will guide the camera manually, tracking to keep the line of text within the camera's relatively wide field of view. On the original Optacon, tracking was accomplished with the non-scanning hand; it is hypothesized here, though, that such information might best be presented at the point of action, in the scanner itself. Since the tracking display can be driven by the microcomputer, the necessary information can be presented in a simplified and unambiguous format, one which -- it is felt -- should require less complex interpretation than does the full vibrotactile display of the original Optacon.

Augmented display capabilities:
As this interface gives us the ability to display computer-generated output on the tactual and visual Optacon displays, we gain for the first time the ability to augment, enhance or otherwise restructure the pattern which is displayed to the user. This could prove to be helpful in improving user performance on the Optacon. For example, certain shapes of letters will be more easily recognizable tactually than others, the specific shapes perhaps varying from user to user. Once a 'tactual alphabet' has been compiled for a user, and once the letters in a text fragment have been identified by optical character recognition techniques, it is a simple matter to display that text in the user's personal tactual alphabet. In fact, should it turn out that the most easily recognizable tactual forms for the user are Braille cells, those patterns can also be generated and displayed. Similar approaches can be used to format displays on the Optacon light box, for use by low-vision individuals.

Research for The Optacon II:
A new version of the Optacon, called Optacon II, is presently under development at Stanford University by Dr. J. Linvill and his team. It will have the same functional capabilities as the original Optacon, but will be reduced in overall dimensions to the size of a cigaret pack, thus making it a one-hand device. Although that group has reasons to preferring a different input camera, with a TV array, they feel that the interface to the Optacon described above is an extremely valuable tool for the development of the opto-electric system for the new package. It will allow the presentation in real time on the tactile and visual display of the current Optacon of computer-generated data, simulating a source under investigation. Electronic zooming and other fundamental algorithms can be tested before hardware implementation.

Spun-off assistive devices:
In the reading aid under development, the Optacon interface board is driven by a microprocessor that interprets data from a hand-held camera. With a different front end, other useful assistive devices using the interface board become possible. For example, a blind or low-vision person might wish to access materials stored in ASCII format on some computer. It is easy to imagine a device which could retrieve the data from storage, and then display it in whichever format is selected -- via voice output using a speech synthesizer, via tactual output using some selected 'tactual alphabet', via a visual display on a light box (also with the possibility of specially designed letter shapes).

Conclusions.
The modular approach in this reading aid project is generating both directly and indirectly useful components. The output interface to the Optacon illustrates this:the reading aid proper has gained an output option for its users; workers in related projects at the VA and at nearby Stanford University have acquired a research tool; and rehabilitative engineering in general has generated a component which should find application in yet other assistive devices.

Acknowledgements
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PROJECT FOR AN OPTICAL CHARACTER RECOGNIZER FOR THE BLIND

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ABSTRACT - A prototype of Optical Character Recognizer for personal use by the blind is described. It is based on microprocessor technology, and performs multifont print recognition at a speed of about ten characters per second, with an error rate less than 5%.

RÉSUMÉ - On décrit un prototype d'identificateur optique de caractères destiné aux aveugles. Cet appareil individuel est basé sur la technologie du microprocesseur. Il identifie des caractères d'imprimerie multipolice à une vitesse d'environ 10 caractères par seconde, avec un taux d'erreur inférieur à 5%.

Introduction

A prototype of Optical Character Recognizer is being developed at the Institute for System Dynamics and Bioengineering (LADSEB) of National Research Council (CNR) of Padua, Italy. The recognizer, which is intended for personal use by the blind, is based on microprocessor technology, and its cost and dimensions have been kept low.

The sequence of operations performed on the printed text to be recognized is shown in Fig. 1. The input function is carried out by a special optoelectronic terminal which contains pre-processing circuitry as well. In the segmentation block, the text is first divided into distinct fields of print, then each field is divided into lines and each line into characters. Feature extraction and recognition are applied to the images of single characters.

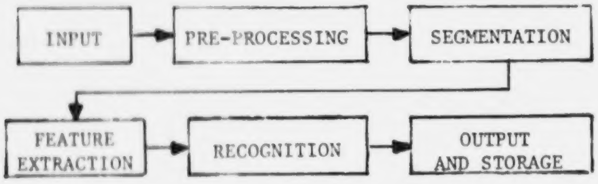

Fig. 1 The Sequence of Operations

The characters are made available to the user at the output terminal, which is interactive and allows either display of Braille-coded lines or synthetic voice.

The processing system is based on a multiple processor structure of the pipe-line type, and extensive use of large-scale integrated electronics has been made throughout.

The Input Terminal

The input terminal, which enters the information of the printed text into the processing system, is based on a moving head equipped with an optoelectronic device formed by a single array of 256 photodiodes, which scans the image through an x-y motion. This motion is controlled by the processing system itself, and allows the image to be scanned with a grid of 0.1 mm x 0.1 mm squares.

The amplitude of the analog output signal is proportional to the average gray level in each element of the grid. This signal is quantized to a sequence of binary values obtained by comparison with an adaptive threshold.

Each sweep of the input terminal allows acquisition of a strip of text 25.6 mm wide and 204.8 mm long, and its subsequent conversion into a matrix of 256 x 2048 bits.

Pre-processing

The digital signal generated by the input terminal is transmitted synchronously to a dedicated hardware device, where the operation of "image thinning" is performed.

This operation preserves the connectivity and form of the sets of black dots on white background, and it is carried out in real time. The ouput data are then fed into an input buffer. A complete strip of printed text can be stored this way.

Division of Text into Fields

The text to be recognized is first examined to determine if the image is divided into separate, distinct fields (headlines, columns of printed text, photographs and drawings).

This analysis is performed on an image of the text which has been reduced by an 8 to 1 ratio, and consists of looking for graphic delimiters and relevant changes in the statistical properties throughout the image. As a result, major properties and coordinates of single fields are recognized and stored, to be made available to the user and assist in the positioning of the moving head on the text.

Division of Fields into Lines

A full-size strip of text is examined to detect the slope and position of printed lines. The slope is estimated by a trial-and-error algorithm which evaluates the maximum alignment of black points. The position of each line is then indicated by a pair of parallel segments which enclose the line and have the predetermined slope.

This set of parameters is used both to assist in the analysis of the next strip and to help in the segmentation of the line into characters.

Division of Lines into Characters

In dealing with this subject, printed characters are considered as distinct, connected sets of black dots, each line being formed by a succession of them. The operation begins with a description of the line as a sequence of sets; to this sequence two different criteria are then applied in order to decide if a character is composed of more than one set, or if a set is formed by two or more characters connected erroneously.

Feature Extraction and Recognition

The images of thinned characters provide two main sets of features, to be used for recognition purposes:

1) topological data, that allow classification of thinned images as ordered graphs of oriented branches;
2) images that have been normalized in size and position through a linear transformation in a 16 x 16 matrix.

Each of the two sets of features is matched with the corresponding data that belong to the resident characters, by means of decision trees that accelerate the procedure; the comparison of the image being entered with each resident character gives two series of figures of probability, which are then weighed and combined in a decision stage.

The resident characters' data were obtained off-line from labelled samples of characters by means of a set of interactive programs, consisting of three main parts:

1) simulation of the whole image processing;
2) cluster analysis applied to the samples;
3) estimation of the error rate, to help in the refinement of both the functions involved in steps 1) and 2), and evaluation of the number of samples; 5% was considered to be the maximum acceptable error rate.

"Topology" and "normalized images" were both found necessary to ensure a sufficiently low error rate; for an example, refer to the following error table:

	Topology Only	Norm. Images Only	Combined Features
Rejection %	23.0	2.1	0.2
Error %	1.7	6.0	4.5
Total Error %	24.7	8.1	4.7

Conditions: 1730 samples were used as reference data, and 1730 other samples were used as unknown objects.

Output and Interaction with the User

The recognized characters may be displayed in sequence to the user, and stored on magnetic tape for subsequent use. There are two prospective methods of output: speech synthesis, performed by a dedicated processor, and Braille-coded output in volatile form through a board of pin matrices. The output terminal allows for man-machine interaction, which assists the user in obtaining correct results.

The Processing System

The basic requirements of the character recognizer, as outlined after a preliminary investigation, were:

1) the already quoted error rate, equal to or less than 5%;
2) a recognition rate of at least ten characters per second;
3) low cost and dimensions.

To fulfill the above conditions the image recognition algorithms were first optimized for reducing execution time and memory occupation. To this purpose extensive work has been carried out on an ordinary minicomputer, using high level language.

The same programs have been transferred later to a program development station based on an 8-bit microcomputer and compiled in assembly language. This was done to allow a more precise evaluation of time requirements. A prototype was then designed, based on a multiple processor structure of the pipe-line type, with one-way data flow, since the whole information processing can be carried out in an open-loop sequence of steps. This structure bears some advantages over the conventional multiple processor, in which a given number of CPU's share several common resources. It does not involve polling techniques, and can be easily divided into functional modules, allowing modular growth.

This research is being partially supported by the Special Project on Biomedical and Clinical Engineering of the National Research Council (CNR).

Acknowledgements

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SONIC ORIENTATION AND NAVIGATIONAL AID (SONA)

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ABSTRACT - A major factor in the problem of independent mobility for a visually impaired person is that of orientation toward the desired destination. The Sonic Orientation and Navigational Aid (SONA) is designed to alleviate this by providing auditory orientiation cues to the blind traveler.

RÉSUMÉ - L'acquisition de l'indépendance de la mobilité est un problème pour les personnes souffrant de troubles visuels, dont un des principaux facteurs est l'orientation vers la destination voulue. L'aide SONA (aide d'orientation et de navigation par ondes sonores) a été conçue pour pallier cette difficulté au moyen de l'émission de repères d'orientation sonores au marcheur aveugle.

Introduction

Factors affecting the independent mobility of a visually disabled person are numerous and complex, including the degree of residual vision (if any), motivation, training, age, adaptive aids being utilized (if any), etc. For a blind traveler, the task of travel itself is very complex, and every element in it is critical. By carefully studying each of these elements to pinpoint the specific area of need and by working closely with the disabled users, the researchers have developed an answer to some of the key questions concerning mobility of the blind and visually impaired population.

The SONA (Sonic Orientation and Navigational Aid) system for blind and visually impaired persons was developed at the Georgia Institute of Technology with funds provided by the Veterans Administration. SONA is not an electronic travel aid (ETA) for wayfinding. Instead, SONA addresses the equally important and often overlooked orientation needs of the blind traveler. It is designed to provide auditory cues to the traveler about the environment by means of sound generating units placed at specific generic locations.

Innovation

The obvious solution to the problem of being unable to find orientation cues is to develop a means of activating the cues by remote control. Before launching into expensive theoretical research, the research team at the Georgia Institute of Technology first examined existing technology for suitable hardware. It was discovered that an ordinary automatic garage door opener already possessed many of the capabilities desired for this device, and the original SONA was based on this technology. A tone generator was substituted for the garage door motor, and the transmitter was rebuilt with a touchtone keypad instead of dip switches, resulting in a system which would serve the blind population as an orientation aid which operates only by radio signal request. The user would carry only the transmitter, enter a three digit code for a specific receiver location (such as a building exit) and only the tone generator mounted over the exit would respond with an audible tone. The tone need only last until the visually impaired traveler has located its origin. He may then stop sending the radio signal. The system did not leave the drafting board until its potential users were given an opportunity to contribute their input and requirements to its design, even though the originator of this concept is a visually impaired researcher.

The present device consists of a microprocessor based radio transmitter, and many microprocessor based radio receivers coupled with audio tone generators which when activated serve to orient the user to many standard features in the environment. A receiver would be mounted at building locations such as elevators, exits, telephones, restrooms, information desks and many other standardized locations. Each receiver would be assigned a three digit code such as 911 for emergency exits, 411 for information centers, 100 for building entrances, etc. The traveler would carry a calculator-size transmitter with a touchtone keypad to transmit any chosen codes. Each transmission would elicit an audio response from that receiver assigned to that code, assuming the traveler is within 75 feet (i.e., 23 meters) of that receiver. The system provides the traveler with information that tells him that the facility sought is nearby and in exactly which direction it lies. The traveler may then localize the sound and "home in" on it using his chosen wayfinding aid. The tone sounds only while the user is pressing the transmit button. SONA is capable of producing a variety of outputs for positive feedback.

Configuration and Features

As stated previously, the visually impaired user carries only the transmitter component which fits easily on a belt pack, in a pocket, or in a purse. The present design has reduced the size of the transmitter to a size slightly larger than a package of cigarettes, though much thicker. Reduction beyond this point may not be feasible since the smallest available touch tone keypad is being utilized and anything smaller than that would be difficult to handle. The visually impaired persons who have held and utilized this device feel that it is easier to hold at its present size.

The transmitter is battery powered and has no "on/off" switch. It is permanently "on" but requires so little standby power that a battery lasts as long as four months at a time before recharging is necessary. No antenna is required and signals do not penetrate between floors in the more modern buildings where SONA has been tested. The keypad configuration is about the same size as that of a touchtone telephone, but the buttons are not raised. The lay-out of the keypad is identical to the touchtone keypad, but each key is recessed so that they cannot be accidentally activated. The transmitter produces a low volume, distinctive tone when enough pressure is exerted to activate the code so that the user will know that all the digits were entered. When the battery voltage does drop with age and use, this tone begins to fade which alerts the user that it is time to recharge the battery.

Once the three digit code has been entered, the user presses the 'send' key. The radio signal is transmitted only while the 'send' key is being pressed and stops as soon as it is released. The receiver generates a tone only while the radio signal is being transmitted. A special feature in the design is that the transmitter remembers the last three digits entered, so that the user simply presses the 'send' key again and again to transmit the same code repeatedly. Entering new digits automatically clears the previous code. There are as many as 20,000 addressable codes available with this hardware, which is more than enough for these purposes. In fact, for simplicity and ease of use, each transmitter is limited to approximately 1,000 codes without internal modification.

The receivers (transponders) are to be placed at key locations such as the entrances of buildings, emergency exits, elevator call buttons, restrooms, etc. Each responds to a unique three digit code by generating a simple "melody" based on the Musical Language for the blind also developed at Georgia Tech which spells out the name of the destination in a series of tones designed to be musically pleasing and easy to recognize. The blind traveler can then localize the sound and move toward it using the usual wayfinding techniques.

The transponders require only a voltage source and a tone generator to turn on and off as needed. They are permanently mounted and can be run at low cost from existing 110-volt electrical supplies. They utilize low-power CMOS circuitry, so that power consumption is less than one watt on standby and less than three while generating a tone. These receiver units also may be battery operated for temporary or remote usage where 110 volt source is not available.

The decoder and tone generator circuit is based on a 6502 CMOS microprocessor, making it possible to create many different types of musical tones and chords, as well as allowing for different types of outputs (e.g.-voice output, vibration generators, etc.). It is also possible to change the function and code of the unit (or even give it more than one function or code) simply by reprogramming the memory chip. In this way, schools and training centers could use the system as a mobility training aid, as a communication aid between instructors and their deaf-blind students (enabling the instructors to communicate with the students without interfering with the students' performance), or for any of a number of specialized functions by simply changing one chip.

Other applications for the deaf-blind population include combining the transmitters with telephones, doorbells, fire alarms, etc., each of which could send a preset code to elicit a different vibratory response which the deaf user can decode to determine what is happening in the environment. This system is similar to others that have been proposed except that it is capable of operation up to 100 feet outside the home. It is also suitable for operation in the industrial environment to signal deaf-blind workers concerning emergencies, equipment status, or messages from the supervisor.

Work will ontinue over the next few months to lower the costs of the units which are now actually acceptable at $100.00 per transmitter and $60.00 per receiver. Since the design is based on microcomputer technology and mass production is expected to lower costs considerably, costs of the receivers could possibly be lowered to approximately $20.00 to $25.00 per unit and transmitter costs can be expected to come down as well. Since mass installation increases the utility of the system it is very likely to become cost competitive with Braille labels which have a much more limited usefulness. The SONA system can offer varying degrees of orientation information on an as-needed basis. It does not depend on tactile sensation, knowledge of Braille, or prior orientation to a given environment. The codes and tonal responses have been designed to be easy to learn and preliminary testing indicates a potential for high acceptance among visually disabled users.

Thirty-five units have been constructed and installed and are being tested at the Atlanta Veterans Administration Medical Center. Further evaluation of this system is invited and encouraged.

TACTILE COMPUTER TERMINAL

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ABSTRACT - The American Foundation for the Blind has designed and developed a Tactile Computer Terminal, which is capable of communicating with any host computer by means of an industry standard serial or parallel interface. This low-cost Terminal can be used to display large print, multi-line braille, or graphics information.

RÉSUMÉ - L'American Foundation for the Blind a conçu et développé un terminal tactile d'ordinateur capable de communiquer avec l'ordinateur principal par l'intermédiaire d'une interface conforme aux séries standard de l'industrie, ou grâce à une interface parallèle. Ce terminal, de prix modique, peut être utilisé pour présenter l'imprimé large, le braille sur plusieurs lignes, et les informations graphiques.

INTRODUCTION

The Tactile Graphics Display incorporated into the Terminal was developed by the American Foundation for the Blind (AFB) under a grant by the National Science Foundation. The Display consists of 1024 pins arranged in a 16 row by 64 column mechanical matrix spaced on tenth-inch centers. Each pin can be selectively raised or lowered under microprocessor control. Because of its symmetrical dot configuration, multiple alphanumeric fonts, conventional six-dot braille, computer-braille, and graphics can be generated. The pins and the background are of sharp contrasting colors which enable the partially sighted to use the display, as well as the blind user.

BASIC SYSTEM DESCRIPTION

Two versions of the Terminal have been under development. These can best be described as "dumb" and "smart". The dumb Terminal is intended to be under direct control of the host computer; therefore it is the user's responsibility to write the appropriate software to drive the Display. A set of primitive commands are provided in order to aid the programmer in communicating with the dumb Terminal.

The smart Terminal provides many additional functions, including the ability to "download" custom fonts, and to re-configure it to respond to whatever control codes are required in order to acheive communication with the host computer. Both versions contain the following common components:

1. Mechanical Display Matrix

The basic Display consists of a block which holds a row of 64 upper and lower pins, and an integral latch bar. These parts are fabricated from various types of injection-molded plastics. The blocks can be interlocked together in order to extend the resolution in both axes. The latch bar moves horizontally within the block. When latched, it maintains the upper pins in either up or down position. Unlatching the specified latch bar enables that particular row of pins to be modified as follows:

An upper pin in the unlatched row is raised or lowered via a lower pin, which also moves horizontally within the latch bar. The lower pin is driven accordingly by a lift bar and lift bar actuator, which are constructed so that moving the lift bar actuator in and out cams the lift bar up and down. In the latched position, the lower pin is moved away from the lift bar, hence neither upper or lower pins can be modified. The lift bar actuators and the latch bars are individually selected by miniature solenoids and are activated by pairs of high torque stepping motors and linear actuators.

2. Display Driver Electronics

The Display is controlled by an 8-bit NMOS 8748 microprocessor, operating at six megahertz. This device was chosen because of its multiple input/output hardware functions and highly efficient program code. The microprocessor supplies stepping pulses and directional signals to the stepper motor and linear actuator controller-I.C.s, and activates the solenoids for row selection and column data via high-voltage interface I.C.s. In order to keep manufacturing costs low, the solenoids are driven in a matrix arrangement, similar to the Display. The high-voltage interface I.C.s drive Power VMOS Field-Effect Transistors, which source and sink current to the respective solenoids to be activated.

DUMB TERMINAL FEATURES

As previously mentioned, the dumb Terminal must be driven directly by a host computer. All display data, such as character fonts or graphics images, are transmitted from the host. Four primitive commands are available in order to assist the programmer in communicating with the Display:

1. Control/A ("ASCII" Command): This command is intended to facilitate the protocol between the dumb Terminal and the host computer by allowing the Terminal to function in a similar manner to a peripheral device such as a printer. The dumb Terminal will interpret an ASCII space character as a pixel to be lowered, and any other ASCII non-space character as a pixel to be raised. In this case, the host will send a sequence of 66 ASCII characters: the "ASCII" command, the row number to be updated, and 64 ASCII characters representing the pixel data.

2. Control/C ("Clear" Command): This command will lower all sixty-four pins on a selected row. It consists of a sequence of two bytes: the "clear" command, and the desired row number to be cleared.

3. Control/R ("Row" Command): This command provides the fastest means of updating a particular row. In this case, the host computer sends a sequence of ten bytes: The "row" command, the desired row number to be updated, and then 8 bytes directly representing the pixel data.

4. Control/S ("Set" Command): This command is mainly provided for test purposes, as it allows the host computer to raise all 64 pins on a desired row. It consists of a two-byte sequence: the "set" command, and the desired row number.

SMART TERMINAL FEATURES

The American Foundation for the Blind is currently developing a smart Terminal, which contains an additional 8085 microprocessor, 2048 bytes of electrically-alterable read-only memory (EAROM), 2048 bytes of random-access memory (RAM), 4096 bytes of non-volatile read-only memory (ROM), and a programmable ASCII keyboard. Although the ROM is preprogrammed with alphanumeric and computer-braille fonts, custom fonts may be utilized by "downloading" the appropriate font information into the EAROM from a host computer. The smart Terminal's control codes are also located in the EAROM, which allows the host computer to configure the Terminal to respond to the required control codes necessary for communication.

The RAM is used as a full-page buffer for data storage and manipulation. The user can direct the Terminal to emulate a standard alphanumeric keyboard, or a computer-braille keyboard (using six keys and the space bar) and can also specify whether the Terminal will display the keystrokes or incoming ASCII data using either alphanumeric or computer-braille fonts. This feature will provide a useful method for teaching braille to sighted persons.

The Terminal can be put into a graphics mode so that the Display can be directly controlled by the host computer in order to show graphics data, such as bar or pie charts.

CONCLUSIONS

The American Foundation for the Blind has developed a dumb Terminal capable of being interfaced with many personal computers such as the Apple and the IBM PC. We are presently developing an intelligent Terminal that emulates a CRT screen. This device is fully buffered permitting multiple transfer rates of up to 9600 baud. The use of EAROMs permits the host computer to adapt the Terminal to its requirements and provides the capability of generating and permanently storing user definable fonts.

A VIDEO MONITOR EMULATOR AND DISPLAY FOR THE VISUALLY IMPAIRED COMPUTER USER

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ABSTRACT - A Video Monitor Emulator and Display, VMED, is a microprocessor based system that when connected to any microcomputer appears as a monitor. The unit processes the composite video signal, recovering the ASCII text and reformats and displays the information in a fashion acceptable to the user.

RÉSUMÉ - L'émulateur et l'affichage de moniteur vidéo (VMED) est un système utilisant un microprocesseur, et il a toutes les apparences d'un moniteur lorsqu'il est raccordé à un micro-ordinateur. Cet organe traite le signal vidéo composite, retourne le texte imprimé en ASCII, le remet en forme et l'affiche d'une manière qui convient à l'usager.

Introduction

While the world of business and many private individuals have been rapidly utilizing the microcomputer for professional and personal reasons, the visually impaired user has been left with expensive and limited means of accessing computerized information and the personal use of a microcomputer has been largely a luxury for such persons. The available means have been limited to a few computers that just happen to display large enough print on a large enough monitor to be useful such as an Apple family or some Radio Shack models. Voice output is of limited use since most software will not address the voice unit and control of what is being read is difficult. Large print terminals are more expensive than the microcomputers, and talking computers are much the same.

A few solutions exist such as using a CCTV to read the microcomputer but this now costs more than the microcomputer, and the list goes on in a similar manner. Briefly, the means developed to date are at best machine dependent and/or software dependent. Quite often they are expensive, and access is limited with few human factors considerations.

Another paper by David A. Ross discusses at length only a few of the human factors considerations in designing an intelligent large print display. The human factors of LPD's have barely been discussed with the predominance of thought having been to make it bigger.

The authors realized that a generic solution is necessary which is neither hardware nor software dependent. They also realized that the system must be an intelligent system, accommodating to the user's needs if it is to be an assistive device. Working together the authors have designed a system that satisfies these needs and can provide the information at low cost to the users and incorporate the essential factors of such a man-machine interface.

The Video Monitor Emulator and Display or VMED, is an intelligent Large Print Display or LPD. It has an on-board microprocessor and can have a variety of possible outputs.

Technical Considerations

The composite video signal which is sent to a video monitor contains all the information needed to reconstruct, and thus reformat, the ASCII text screen. This may be done by taking advantage of the means by which a composite video signal is coded. The video signal is simply a serial string of screen memory bits which have been shifted out of memory at a rate compatible with the particular video monitor and with certain sync bits added to synchronize the video image with the monitor horizontal line scan.

By using this signal the video image from any computer can be quickly mapped into a separate screen memory and reformatted. The dot matrix patterns which form each letter can then be used to determine the ASCII character from which it was constructed. Using this ASCII character screen map one could then reformat a video screen using a large character set and also provide the option of speech, Braille, or a Musical Language in conjunction with the large print characters.

The advantage of using the video output signal is in the standardization of this signal over the lack of standardization of any other part of the video output process in computers. In other words, it is the one place one can hook into any computer and be sure of the formatting of the signal and then reformat it to suit their particular needs, regardless of the type of computer. Thus, this system could be a one-size-fits-all box that plugs in between the video output jack on any computer and the video input jack on the particular monitor chosen.

The actual hardware in this connecting box would consist of "fast" shift-in-and-mask logic which would "catch" the video signal bits and store them into a screen memory for a microprocessor which would then decode this matrix information into ASCII characters and then reformat it for large print display and/or add the Musical Language output to it. This box could be connected to a joystick which would control the screen "window" and could be used to scan over to and examine text written on any part of what the computer has defined as the video screen. The box could also be "smart" enough to recognize and enlarge graphics along with ASCII characters, making it useful no matter what kind of video display the computer being used is producing.

Impact

This unique system promises to be a universal means to interface persons with a visual impairment to existing and future microcomputer equipment. It provides an opportunity for user chosen features such as size, color (both foreground and background), alternate outputs, such as speech, Musical Language, and/or Braille, and a variety of chosen formats as discussed in Mr. Ross's paper on human factors considerations for LPD design.

The unit is expected to have a comparatively low cost though the circuit design as of this writing is not complete. Certainly options such as transient Braille display, or voice will increase the cost, however these options can be auxiliary.

The fact that the microcomputer "sees" the VMED as a monitor is an advantage since even protected software using alternate screens or video output routines will work with this unit, a criticism of some existing units which "grab" characters via a plug in card. In this sense, the VMED is similar to the "keyboard emulators" developed for the input of information to the computer. It is transparent to the machine and the software of the machine. It is anticipated to be comparable in pricing, depending on complexity desired.

The research team is in close contact with an interested manufacturer who is experienced in computer peripherals. Depending on funding the design of initial units will proceed for field testing. This system is presently being designed and built at the Atlanta Veterans Administration Medical Center.

A MICROPROCESSOR-BASED LARGE PRINT READING/WRITING SYSTEM FOR THE VISUALLY IMPAIRED PERSON

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ABSTRACT - This system is based upon the battery powered portable Sony word processor, the Typecorder. The Typecorder has been modified to accept an intelligent interface and a large print display suitable for use by visually impaired persons.

RÉSUMÉ - Ce système repose sur le système de traitement de texte portable et à pile de SONY, le Typecoder. On a modifié ce dernier en lui ajoutant une interface intelligente et un affichage de gros caractères convenant aux personnes ayant des troubles visuels.

Introduction

There are more than two million functionally blind persons in the United States and approximately 70% of them have usable residual vision. These persons cannot benefit from materials written in ordinary print and must rely on some adaptive aid to read printed material. In addition, many of them have considerable difficulty writing and organizing information for daily use, education or employment. This often limits opportunities for improving the quality of life for such persons and may even lead to a dependence on others that is not necessary.

Innovation

Approximately four years ago, the principal investigator surveyed a population of visually impaired adults and determined that a majority of them were interested in an alternative that existed in conceptual form only. The alternative is an analog of the cassette Braille machines which pervade the market for the blind Braille reader.

Included in the survey were questions concerning hypothetical features of the proposed device and potentials for its use. Though the sample was small (only 22 persons) the data was quite definitive. Almost 70% indicated that they would use such a device if it existed and provided a criteria set for its performance. The research team then set about designing and constructing such a device. The details of the development that followed are recorded in past literature and this paper primarily addresses the outcome.

With the advent of the Sony Typecorder, the research team concentrated its efforts on modification of that machine to provide large print that was of a quality and a size that it would have optimal utility to the population that would need it. The survey had indicated that a green display the size of "standard" large print (about 18 point type) would be suitable. Additional data was gathered and it was determined that this size type sells very well in the form of the Reader's Digest Large Print Edition with 305,000 subscribers and the New York Large Type Weekly with 60,000 subscribers.

The present cost of large print books is approximately 40 cents per page and the circulation and sale is so limited that accurate figures are not obtainable as to its ultimate desirability. It was therefore determined to utilize a display with a character height of .2 inches, which is just slightly large than 18 point, and one that can be filtered to any desired color. The display is a 40 character display which is the same as is presently used on the Typecorder.

Technical Considerations

The Sony Typecorder is designed around the 1802 CMOS microprocessor manufactured by RCA. It is interfaced to an Hitachi HD43160 LCD display controller/character generator. This controller accepts ASCII characters and displays them on an alphanumeric LCD display. The character set of the controller is standard ASCII except for three characters. For ASCII backslash (92) the controller displays the "cents" symbol. For ASCII tilde (126) the controller displays a right pointing arrow. For ASCII DEL (127) the controller displays a left pointing arrow.

Every time the LCD display is updated, it is completely rewritten. It first goes through a series of position cursor and writes data instructions for all 40 character positions. An ASCII NULL (00) character is written for positions that have not been entered by the user (which is interpreted as a blank by the HD43160). Once the line has been rewritten, the line number-page number prompt at the end of the line is then written. Finally, the cursor is returned to the next character position to be typed. Before each character is written to the display, the microprocessor checks if the display is busy. If it is busy, the Typecorder waits until the display is available before sending out the next character.

The new display that the Typecorder is to be interfaced with is the Deca 245A. It is a vacuum tube fluorescent display which operates similarly to the HD43160. It accepts ASCII characters and presents them on a bright fluorescent display. The character set of the 245A is a standard ASCII display set. To accommodate the three differing characters that the Typecorder displays, the programming of the Deca 245A was altered slightly so that it would display those characters.

To connect the Typecorder to the Deca display, an interface circuit is required which performs three functions. First, it allows the Typecorder to handshake with the Deco display, telling the Typecorder when the display is busy. Second, it transforms the Typecorder's cursor instructions into characters recognized by the Deca display. Third, it provides electrical isolation between the CMOS circuitry of the Typecorder and the TTL circuitry of the Deca.

The circuit consists of three chips. They are:
1) 2716 memory EPROM
2) 4503 three-state hex buffer
3) 4572 hex gate (1 NAND, 1 NOR, 4 NOT's)

The 2716 provides the necessary character and command transformations, and the other chips provide the handshaking and electrical buffering.

Results

The completed prototypes now offer an alternative display with 40 characters of .2 inch character height. The display is of high resolution and considerable brightness. Preliminary tests indicate it to be of great value to the population that needs it at a reasonable cost, especially when compared to the alternatives.

The Typecorder presently sells for $700.00 as of this writing and the intelligent buffer with display will very likely cost somewhat more in limited production. Negotiations are proceeding with a manufacturer to get this valuable device on the market.

The advantages of this system are that Sony Corporation can provide maintenance almost everywhere to the Typecorder which has already proven to be an extremely reliable piece of equipment. The add-on display unit is modular and can be exchanged by unplugging one unit and plugging in another. This modular design provides for a speedy "trade-in" if repairs should be necessary.

Problems remaining include the provision of reading materials on the Sony microcassette format and the legal repercussions of such an attempt. The software/hardware obviously exists to accomplish this in an economical fashion. Optical character recognition devices that can translate print to ASCII and input the information into word processors or microcomputers are readily available at reasonable prices. Software such as the Holladay program that translate Versibraille to ASCII text files on an Apple II to Sony Typecorder format already exist. This problem is not insurmountable and is precisely that of the cassette-Braille machines.

READING INKBRAILLE WITH THE OPTACON

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ABSTRACT - Blind readers used the Optacon to read a reduced-size ink-image version of braille (Inkbraille). All subjects read Inkbraille easily and reading rate improved with exposure. Inkbraille reading rates are lower than embossed braille rates, probably due to limitations imposed by the Optacon.

RÉSUMÉ - Des sujets atteints de cécité ont utilisé l'appareil Optacon pour lire une image à l'encre qui est une version du braille, mais qui présente des caractères plus petits (Encrebraille). Tous les sujets ont lu facilement l'Encrebraille et la vitesse de lecture s'est accrue avec le temps. Les vitesses de lecture de l'Encrebraille sont plus faibles que dans le cas du braille habituel, probablement à cause des limites imposées par l'appareil Optacon.

INTRODUCTION. Embossed braille reading rates of about 100 words per minute (WPM) are common. No other tactile-based reading system allows the blind to read at that rate. There are, however, major disadvantages to embossed braille. It is bulky, costly to produce/distribute/store and subject to deterioration through repeated use. A reading aid that would convert an ink image of the braille code to a direct tactile facsimile might retain the high reading rate advantage of embossed braille, while eliminating its major disadvantages. Inkbraille was conceived (1, 2, 3) as a possible input code for a new "reading system". Inkbraille is a reduced-size ink-image version of the familiar braille code. It can be simply and inexpensively produced on paper and it's use could result in books for the blind of a size similar to those for the sighted.

In pilot studies the concerns of Inkbraille production were addressed, its readability tested, and the ease with which skilled embossed braille readers learned to read Inkbraille was investigated. In the present study additional data on Inkbraille reading performance were acquired. The results of both of these studies tend to encourage the idea that Inkbraille has merit as the possible basis for a new tactual reading system. Additionally, use of the Optacon to read Inkbraille enabled a seemingly useful comparison of Optacon/Inkbraille versus Optacon/letterprint performance.

METHODS. In the absence of a device designed specifically to read Inkbraille it was decided to use the tactile Optacon (4) as an Inkbraille testing tool. This was convenient in that an Optacon was readily available and the characteristics of Optacon reading were familiar (5 and 6).

Production of Inkbraille was accomplished through the use of an Apple II computer, a Diablo 1620 daisy-wheel printer, some accessories, and two software packages. A software package called Braille-Edit (7) permitted the entry of text from the Apple II keyboard. This text information was translated into a grade II braille Apple text-file by the Braille-Edit program. A second program developed by Dr. Robert Stepp of the University of Illinois at Urbana-Champaign was then used to convert the Grade II Apple text-files into Inkbraille text via the Diablo printer.

A portion of text encoded in standard embossed braille having a page area of ten square inches contains a maximum of 100 braille cells. The same area may contain up to 298 Inkbraille cells (current-version), or up to 719 letters/letterspaces (twelve letterspaces/six lines per inch). Based on these figures Inkbraille reduces the spatial requirements for a given text by greater than 66% when compared with embossed braille.

This study involved five accomplished embossed braille and practiced Optacon letterprint readers that ranged in age from 26 to 66 years. Each of the subjects used the Optacon to silently read three Inkbraille, and three letterprint texts during each of five experimental sessions. In addition, for comparative purposes, these subjects were asked to read one embossed braille text per session. Thus each subject silently read a total of fifteen Inkbraille, fifteen letterprint and five embossed braille texts. The series of five experimental sessions extended over a period of 2 1/2 weeks. After reading each text the subjects were asked to summarize what they had read. All subjects read the same texts but the order of presentation and text medium were randomized.

Texts were selected from the Reader's Digest column "Life in These United States". Inkbraille texts (grade II) consisted of eight lines of about 40 cells per line. Letterprint texts were eight lines in length, and each line contained about 51 letterspaces.

Prior to each mode of reading (Inkbraille or letterprint) the subject was given the opportunity to adjust the Optacon system controls.

Warm-up texts, identical in format to the Inkbraille and the letterprint experimental texts, were used for this procedure. When each experimental text was positioned for reading, the subject was asked to find the first element (Inkbraille cell or letter) of the first text line. When the "commence reading" instruction was given to the subject, a stopwatch was activated. The timer was stopped when the subject initiated a line-changing movement after reading the eighth text line, and the elapsed time was recorded. The time required for each subject to read each text, along with the text statistics constitute the primary raw data of this study.

RESULTS. Letterprint Reading. As anticipated, there appeared to be no trend in the letterprint reading data (individual or group) over the course of the five experimental sessions. The mean rate of letterprint reading was 136 LSPM (letterspaces per minute), or alternatively 25.3 WPM. The individual (fifteen text readings/five experimental sessions) mean rates ranged from 37 LSPM (6.8 WPM) to 296 LSPM (55 WPM).

Inkbraille Reading. Unlike the letterprint reading performance data the Inkbraille data show an increase in reading rate across the five experimental sessions (for the group, as well as individual performance). These readers were able to read Inkbraille upon initial exposure, and limited practice improved their performance. The mean Inkbraille reading rate ranged from 86 BCPM (20.4 WPM) to 124 BCPM (29.5 WPM) for the fifth session. Clearly, Inkbraille reading rate tended to improve across the five experimental sessions.

Embossed Braille Reading. These subjects read embossed braille at a mean rate of 115.7 WPM. There was no observable trend in this performance over the five experimental sessions. As is readily apparent, embossed braille reading was accomplished at a rate about four times faster than either letterprint or Inkbraille reading.

DISCUSSION. Letterprint reading rate was relatively constant across subjects or across sessions. This lack of a trend was not unexpected, because these five subjects were practiced Optacon letterprint readers. Consequently, 136 LSPM (25.3 WPM) is a reasonable estimate of the mean letterprint reading rate for this group.

Inkbraille mean reading rate increased across the experimental sessions, a result more or less expected, based on previous studies(1,2,3). Each of the five subjects demonstrated an improved performance over the course of the five experimental sessions; furthermore, group performance improved consistently from session one to session five. With familiarity and practice this group of subjects was able to attain a mean reading rate of 124 BCPM (29.5 WPM) during the fifth session.

The fifth session mean Inkbraille reading rate cited above may be considered as a steady-state rate (a reasonable assumption). When compared to the letterprint based performance of 136 LSPM (25.3 WPM) it would appear, that Optacon/Inkbraille reading rate was somewhat higher than the Optacon/letterprint rate. This apparent difference in performance can be accounted for by considering the effect of the use of "contractions" in grade II braille.

Due to the use of contractions the Inkbraille texts used in this study consisted of 23% fewer symbols than letterprint versions of these same texts would have contained. Reading rate measured in symbols (e.g., letterspaces per unit time) appears to be constant (6). A text encoded in Grade II Inkbraille would appear to be read faster than the same text encoded in letterprint simply because the braille text contains fewer symbols. When the mean reading rate for Inkbraille is adjusted, taking into account braille contractions, the apparent difference between Inkbraillle and letterprint rates disappears.

In summary, it seems reasonable to conclude that Inkbraille can be easily read by the blind, and that significant increases in reading rate can be accomplished after relatively little exposure. Since there is little difference in reading rates for Inkbraille and letterprint when both are read with the Optacon, one is prompted to believe that the Optacon introduces a rate-limiting constraint. The Optacon, appropriately designed with high resolution required for reading letterprint (but inappropriate for the simpler braille code), was used in this study primarily for purposes of expediency. We thus conclude that the large observed difference between embossed braille and Optacon/Inkbraille reading rates resulted from the use of the Optacon in the present study. We are optimistic that an appropriate translating device may result in considerably higher Inkbraille reading rates.

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ENVIRONMENTAL CONTROL SYSTEMS/
SYSTÈMES DE CONTRÔLE DE L'ENVIRONNEMENT

THE MicroDEC ENVIRONMENTAL CONTROL SYSTEM: WHAT DO USERS DO WITH IT? - A PRELIMINARY STUDY

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ABSTRACT - Developed in 1979, the MicroDEC Environmental Control System has been commercially available for four years. It was the first system to eliminate direct wire connections by using power-line wiring to send control codes to each device. A preliminary study of how people are using the system is presented as a means of defining applications and future design objectives.

RÉSUMÉ - Mis au point en 1979, le système de commande environnemental MicroDEC est disponible sur le marché depuis quatre ans. Il s'agissait du premier système permettant d'éliminer les connexions directes par câblage de secteur pour commander chaque appareil. Une étude préliminaire de la façon dont les gens utilisent le système est présentée comme un moyen de définir des applications et d'établir de futurs objectifs de conception.

INTRODUCTION

The MicroDEC (Microprocessor-based Distributed Environmental Controller) system was developed by the Rehabilitation Engineering Program of Northwestern University in 1979. It was the first commercial device controller to utilize existing power-line wiring to transmit coded signals from the controller console to receiver units connected to each device (1). By eliminating the need for direct wiring, a requirement of device control systems available at that time (2), the MicroDEC gained the advantages of less difficult installation, a less cluttered appearance, and greater flexibility in arranging the completed system in the person's environment.

The design of the MicroDEC incorporated a number of other innovations. It also consolidated useful features found in earlier separate systems. A partial listing of key features follows:

- Compatible with BSR X-10 Home Control System
- Integrated telephone/speakerphone control
- Remote operation through radio link
- User programmable features
  - Beeper tones for nonvisual operation
  - Telephone number selection and storage
  - Display limit to actual devices connected
  - Device definition as latching or momentary
  - Exclusion of phone functions from display
- Special remote peripheral modules
  - Alarm buzzer
  - Electrical contact closure module
  - Electric bed controller
- Integrated switch control for users of MED Quad powered wheelchair system

Since the MicroDEC was commercially introduced in early 1980 by Medical Equipment Distributors, Inc., over 225 systems have been purchased and installed. Though this figure indicates that the MicroDEC's overall design has achieved a degree of success, a systematic follow-up was proposed to determine the actual importance of specific features. To obtain details of post-installation use, a survey was developed by the authors and administered for evaluation.

SURVEY METHODOLOGY

In this preliminary study, ten of the survey respondents had been clients of author R.G. Each had been evaluated for environmental control and had subsequently received a MicroDEC system after June, 1981. Two additional respondents (A and H) were known to the authors, but had acquired their systems on their own initiative from a vendor.

The survey, which required 30 to 50 minutes to complete, was conducted by telephone interview. It consisted of a series of questions selected to determine: 1) the degree of instruction required to achieve competency and confidence in use of the MicroDEC, 2) the degree of familiarity with the physical setup of the equipment and its operation, 3) the method and circumstances of controlling the MicroDEC, 4) the arrangement of the respondent's current system, 5) the respondent's personal assessment of various features of the MicroDEC, 6) the reliability of the MicroDEC hardware, and 7) the user's overall impression of the system.

SURVEY RESULTS

Table 1 presents an overview of each respondent's MicroDEC system as it was set up at the time of the interview. Additional data as well as conclusions derived from the survey results will be prepared in an internal NUREP report. This report will be made available upon request.

ACKNOWLEDGEMENT

This work was supported in part by the National Institute of Handicapped Research Grant G008300070.

TABLE 1. Data from preliminary survey of MicroDEC users.

Respondent	A	B	C	D	E	F	G	H	I	J	K	L
Gender	M	M	M	M	F	M	M	M	M	M	M	M
Age	20	24	20	35	58	17	32	22	37	33	26	18
Disability:												
Spinal cord injury	C4	C2	C5	C2		C4	C4	C4-5	C5	C4-5	C4	C4
Post polio					+							
Funding for MicroDEC:												
Personal/family				+	+			+	+			
Private insurance		+	+			+					+	+
Free funds <a>	+						+			+		
Time from disability onset to installation	2y1m	1y1m	1y5m	1y10m	28y	8m	9m	3y11m	3y3m	10m	7m	1y
Date of installation	12/80	8/81	10/81	10/81	12/81	1/82	6/82	6/82	7/82	12/82	2/83	3/83
Home installation by:												
occupational therapist			+		+	+	+		+	+	+	
rehabilitation engineer					+	+	+		+	+	+	
other	+	+		+				+				+
MicroDEC location:												
bedroom	+	+	+	+	+	+		+	+			+
common room							+			+	+	
Remote control from wheelchair:												
pneumatic	+	<d>		+		+	+	+			+	+
hand switch			+		<d>				+	+		
Same controller for chair	+	+		+	+	+	+	+	+	<f>	+	+
Control from bed:												
pneumatic		+		+	+	+		+			+	+
hand switch			+									
Feedback used: <b>												
visual display only	+				+	+	+		+	+		
audio tones only	+	+	+					+			+	+
display with tones	+		+	+			+	+			+	+
Devices controlled:												
alarm buzzer	1	1	<e>	1	1	1	<e>		1	1	1	1
lamp or room light	2	2		3	4	2		3	2	1	3	1
TV (on/off)	1	1		1		1		1	1	1	1	1
TV (channels)				1		1		<e>	1	1	1	1
radio/stereo (on/off)	1	2		1	1	<e>	<e>	1			1	1
electric bed		1				1						
other	1			1	5							
Speakerphone	+	+	+		+	+	+	+	+	+	+	<e>
Device distribution: <c>												
single room		+	+	+		+	+		+	+		+
multiple rooms	+				+			+			+	

Notes: <a> Free funds are corporate/private donations administered by the Rehabilitation Institute of Chicago.
<b> Feedback used for control. All respondents used the visual display for programming.
<c> Distribution excludes buzzer or radio used to signal for assistance; generally in separate room.
<d> Respondent has the control interface, but does not use it.
<e> Respondent has used the device, but did not have it in the system at the time of the interview.
<f> The respondent uses only a manual chair when in his home.

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AN ENVIRONMENTAL CONTROL UNIT FOR REHABILITATION HOSPITAL USE

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ABSTRACT - This paper describes a system allowing high-level spinal cord injured clients control of their nurse call, bed, tv, over head light and other functions. The system has an unusual "program mode," allowing clients and staff to set the unit to skip unwanted functions. This gives faster access to desired functions or restricts use of certain functions.

RÉSUMÉ - La présente communication expose un système qui permet aux grands blessés médullaires d'appeler leur infirmière, d'actionner leur lit, d'allumer la télévision ou leur lampe, et de commander d'autres fonctions. Ce système possède une caractéristique originale: le mode "programme" grâce auquel le malade ou le personnel soignant de l'unité peut invalider les fonctions non désirées. De cette façon le temps d'accès aux fonctions désirées est plus court, alors que l'emploi d'autres fonctions est interdit.

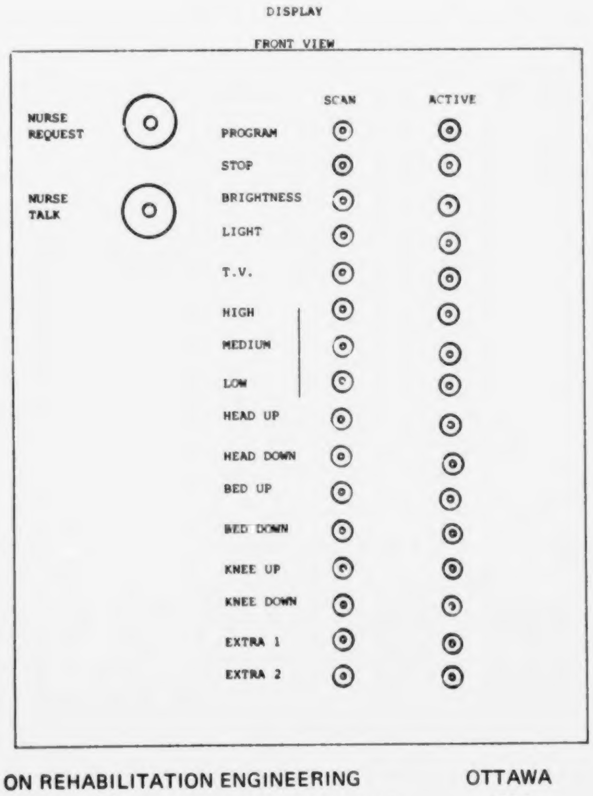
Introduction

Environmental Control Units (ECU)'s for hospital use can differ from home use ECU's in two aspects. First, the devices to be controlled generally are within the client's room rather than spread out through several rooms as would be the case at home. Secondly, devices to be controlled will be fairly standard within each hospital. For these reasons, as well as a means to explore new ideas, a nursing ECU (NECU) was constructed.

As shown in Photo 1 and Figure 1, the display has two large lights and two columns of 16 lights each. The large lights indicate the user has requested a nurse or that the nurse is responding. The nurse call is activated by blowing on the control tube or one action of a dual action switch. The nurse call goes directly to the nursing station without processing by the NECU electronics. The left SCAN column sequentially presents options to the user. Selected outputs are shown by the right ACTIVE column.

The ECU allows clients sip control of the program mode,(discussed later) allows display scanning to be stopped, the display to be dimmed, overhead light, tv, three volume levels of the tv, the three bed functions and two extra functions.

FIGURE 1
HOSPITAL ECU



Normal Operation

In normal operation the left column is scanned from top to bottom. If the client wishes to change the lit function he sips, otherwise, he does nothing.

Program Mode

The program mode has two purposes:

1) It allows hospital personnel to restrict a client's use of functions controlled by the NECU. For example, it is possible to prevent use of high tv volume or restrict bed motions.
2) It allows a client who has mastered normal NECU operation more flexibility when using the unit.

A rear switch controls whether the program option is scanned or skipped. If the switch is enabled, scanning will include the program mode option, otherwise, scanning will start at "STOP". If the user sips when program mode is lit, the following occurs:

1) The programming mode active light will start flashing and the unit will scan through all functions.
2) The active row now shows the active functions, that is the functions to be scanned in regular mode.

Please note, any changes while in the programming mode will not affect any of the operations controlled by the NECU, rather it will change the selections that are scanned when the normal mode resumes. For example, if a user wants the headboard light on for the next hour, but wants to control the tv rapidly, he can do the following steps:

1) In the regular mode, turn on the headboard light.
2) Leave regular mode and enter program mode by sipping when the program light is lit.
3) If an undesired function is enabled, sip as its scan light is lit. Determine which tv volume levels are desired and deselect the undesired volume levels.

When only the program, tv, and desired volume level active lights are lit, go to step 4.

4) Leave the program mode and reenter regular mode by sipping when the program mode scan light is lit.

The NECU will now scan through only the program mode, tv, and the volume levels selected.

When the user wants to turn off the headboard light, he reenters the program mode, enables the headboard light, reenters the normal mode and turns off the headboard light.

There are two differences between normal scanning and program mode scanning. First, corresponding pairs of bed functions light up together. This was done because it makes little sense to be able to move the bed in one direction without returning it to the original position. The second difference between normal and program mode scanning is the tv and volume selections.

If the tv selection is skipped, the volume selection lights will also be skipped when returned to the normal mode. However, the NECU will remember which volume selections were enabled. Take the following example: Presently the NECU scans through the tv, high, and medium volumes but not low volume. The user now reprograms the NECU to skip the tv function. When scanning resumes, tv and volume options will not be presented to the user. However, when the NECU is again programmed to scan through the tv option, it will remember to scan through high and medium volumes and that low volume is to be skipped.

At present the NECU has been tried by one client. Use was discontinued for two reasons: First the client was shown the device shortly post injury and was not emotionally ready to use it. Secondly, clients are alternately positioned on their right and left side, therefore being able to observe the display only half the time. It is hoped different displays can be developed to solve this problem.

The paper was presented to share a technique to speed use of environmental control systems.

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SONA-ECS, AN ENVIRONMENTAL CONTROL SYSTEM

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ABSTRACT - The SONA-ECS evolved from the SONA system for the orientation of the blind or visually impaired traveler. This system provides low cost decentralized environmental control which can be customized to meet the needs of a greatly diversified population.

RÉSUMÉ - Le ECS de SONA, qui a évolué à partir du système SONA, sert à l'orientation du marcheur aveugle ou souffrant de troubles visuels. Ce système est composé d'un dispositif de commande décentralisée de l'environnement (peu coûteux), qu'il est possible d'adapter aux besoins de diverses personnes.

Introduction

Environmental control systems have evolved over the past five years from cumbersome and extremely expensive systems to more reasonably priced smaller microcomputer based systems. Some of these systems have actually progressed to such a degree of portability that they can be easily integrated into the design of powered wheelchairs. Most current systems are limited in that they are not modular enough, have a high "starter" unit cost, are too centralized, and have limited flexibility and versatility.

Most of the existing units work though a central terminal or transmitter that sends a signal to a receiver that controls the actual appliance. This type of system is impressive as long as reliable operation of the central unit is maintained. Any failure within this central unit will cause the system to lose its integrity. Maintaining a duplicate central terminal in case of failure of the main central control is expensive and physically cumbersome.

In contrast, the SONA-ECS system avoids many of the above problems and provides the consumer with the kind of optimal environmental control system that up until this time he has been unable to buy at any price.

Innovation

The SONA-ECS system was first designed approximately two years ago. The first system was a comparatively crude one-function device which utilized a hand-held garage door opener transmitter and receiver which switched one device on or off. Initial tests with this system demonstrated the value of a decentralized system with high portability and low cost.

This original system evolved quickly into a system of multiple function receivers. One transmitter could send three digit codes to receivers and each multifunction receiver could emulate four independent receivers. This provided cluster control. One box can control four functions that are grouped together, such as electronic door lock, electronic door opener, lights, and perhaps a security system. The cost of such a receiver is modest and the transmitter is a portable 10 cm X 6 cm X 4 cm and has a touch-tone keypad. While it is admitted that a touch-tone pad cannot be used by all disabled persons, it is pointed out that many disabled persons can use touch-tone with the assistance of another aid.

The system has been recently redesigned to allow greater flexibility and versatility of use by a more varied population. The transmitter is now microprocessor based using a one chip microcomputer, the Motorola 1468705 CMOS microprocessor. The transmitter is also CMOS for lowest power consumption and highest reliability. The complete new transmitter assembly will be slightly smaller than the existing one and will run on a single 9 volt battery for six to eight months at a time, depending on frequency of use.

The new receiver is based on the Intel 8748 microprocessor. This microprocessor decodes all incoming signals and controls all aspects of the receiver's functions. Together with a programmable interval timer chip (the 8253) this microprocessor provides pulse control for the newly included electronic triac dimmer circuits and audio output status display. Each of these receivers can provide control over as many as six devices. Actually, it could control as many as 256 devices, but six seemed to be a maximum practical number of devices for any particular clustering of appliances, etc. In homes where this may be designed as an integral system to the house, this receiver could easily handle as many devices as could physically be grouped into one area.

Each of these receiver units has two dimmer circuits and four switched circuits. Each dimmer is independent and can handle up to a 600 watt load.

The Coding System

The system hardware while advanced is not so surprising or unusual as the software. The coding for the transmission consists of a 20 bit sequence sent at 300 baud. There is a start bit, seven generic code bits, and twelve bits of address code. The transmitter sends binary coded decimal so a three digit code is always the address code. The seven bit generic code allows multiple systems to operate in the same area without conflict. The total number of codes using this scheme is approximately 150,000.

Eleven keys of the touch-tone keypad on the transmitter may be used for the three digit code. The twelfth is for transmission. Obviously, other inputs may be used other than the keypad.

The receiver has a generic code plus address code. The address code is set from the transmitter unit by a special interface provided on each unit.

Interfacing

The transmitter is provided with a serial interface capable of communicating with most microcomputer equipment via RS-232/C. This unique serial interface has the additional capability of allowing the transmitter to communicate to the receiver for programming purposes. A cable can be connected from a transmitter to the receiver and numbers entered on the transmitter will be sent to the receiver via the cable. The receiver can then provide a series of pulsed musical notes to indicate the number it has just set in memory. This number will then be the address code of that receiver. This provides user programmability and still preserves the generic differences between units to prevent inadvertent interference.

Obviously, a redundancy scheme is used on transmission with check routines to determine the exactness of each code received upon transmitting a signal to any receiver. This nullifies any possibility of a "false" signal caused from interference.

The unique interface provided on these units allows surprising versatility. It permits each transmitter to be operated from almost any microcomputer circuit and, therefore, is automatically compatible with virtually every keyboard emulator. It may be operated under programmed control, timed control, or any of a number of other types of control now under development. This versatility and flexibility provides enormous advantages in economy of scale production while preserving custom designed features.

With software modification, the receivers can be operated as a direct switch unit from digital sources, though the rf link probably provides a more practical link in terms of operating as a switch unit. However, one unique feature is the ability to operate as a digital receiver and send any codes received to a microcomputer where the computer under program control can perform all the functions that such control provides, including dialing a telephone and giving a message, creating text, operating a communications system, operating a robot, operating a security system, etc.

Additional Features

To date, surveys of the users have shown that the most attractive features in this system are its versatility and its portability. The unit is small enough to be mounted on a wheelchair or be carried by a person. The receivers may be used not only to switch on and dim normal lighting but to control many devices and appliances including radios, tape recorders, stereos, etc. The receiver is equipped to drive VMOS transistors for proportional control of volume, tone, and balance on TV's, radios, stereos, and intercoms, etc.

Prototype units have been tested in vans for remote operation of doors and lifts at distances of up to 80 feet. Sound emitting receivers have been built that act as remote control doorbells or as a summons for an attendant or family member.

Initial Evaluation

Tests of the output circuitry and the transmitting and receiving equipment have been continuing for more than 4000 hours of operation. The early generation prototype units using hardware circuitry rather than the newer microprocessor circuits have been used by quadriplegics in their homes for some two years in one case. In the case of another participant, this system was used in the office and in the home for another two years. Units have been built into an advanced home of the future in Florida where the units control 54 functions including lighting, drapery pulls, etc.

The failure rate has been very low and experience with the original prototype units has led to the more advanced units discussed here. These units are now under construction in sufficient quantity for field testing. One major delay was encountered in producing the new unit when it was discovered that the Motorola 146805 microprocessor used in the transmitter is so new that only limited quantities are currently available. This microprocessor is presently the single most expensive component in the system but this is expected to change within the next year.

In summary, SONA-ECS is a modular system intended to interface with today's and tomorrow's technology. It does not limit the user by its hardware and frustrate those attempting to develop custom designed systems by its limitations.

The projected cost of the system is quite low. The component cost for each six-function receiver is approximately $75.00 and the transmitter cost is presently about $100.00. Since the system is based on microcomputer technology, it is anticipated that costs may well come down considerably on the transmitter and moderately on the receivers.

In production, this system offers the promise of the first truly decentralized portable system which is modular and can therefore serve the needs of a few to a great many persons at a cost of less than $20.00 per function for the receivers and an estimated $100.00 per transmitter. This low cost combined with the compatibility with other equipment, the modular nature of the system, and the decentralized portability of the units has earned this system the highest ratings of all systems tested by users to date.

Availability

The system is being considered by one manufacturer now for mass production upon completion of advanced field testing by the Veterans Administration. Custom designed units are now available from a local small business in Atlanta, Georgia.

A PORTABLE SIMULATOR OF ENVIRONMENTAL CONTROL SYSTEM (ECS)

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ABSTRACT - A portable ECS-simulator assisted by microcomputer was developed and evaluated. It is concluded that the simulator can be utilized effectively to a severely physically disabled wherever he is, without any technical difficulties for medical staffs to teach how to operate sensors and ECS.

RÉSUMÉ - On a élaboré et évalué un simulateur portative de ECS (système de commande de l'environnement). La conclusion tirée est que ce simulateur peut être d'une efficacité considérable pour les grands handicapés, où qu'ils soient, tout en soulageant le personnel médical des difficultés techniques propres à l'enseignement du fonctionnement des capteurs et de l'ECS.

ECS has been developed for severely physically disabled people. However, there are two major problems to be solved for the wide spread of ECS. The first problem is that the medical staffs do not always have enough idea about ECS in selecting patients to be applied ECS. The second problem is that a few patients can't realize the sensor operation and get confusing in understanding operational procedure ;the relation between sensor operation and activity of ECS. In the first problem, medical staffs need courses with some assistive devices to get knowledge on ECS. In the second problem, some training programs are required and a patient should use either an actual ECS or other simulative system of ECS. It is considered from above breif analysis that an apparatus, which simulates the function of ECS and has several training functions on operating sensors and ECS, is suitable for one of solutions to these problems. In addition, the apparatus should be portable to be used for home-bound severely physically disabled patients. We have developed a portable apparatus, called ECS-simulator, and it was clinically evaluated.

The block diagram of the simulator is shown in Fig.1. The simulator is composed of microcomputer board (Apple 11 with 48K RAM, without keyboard), a ROM card, a power supply, a RF modulator, sensors, an antenna cable, and a portable trunk. The board is not modified at all. Sensors are connected to game I/O terminal on the board. Any types of binary switches are avairable for sensors. All units including sensors are packed into the portable trunk as shown in Fig.2. The weight of the simulator is about 7 Kg, and it is easy to bring it anywhere. A generally used color television set (TV) is only required as a monitor display .

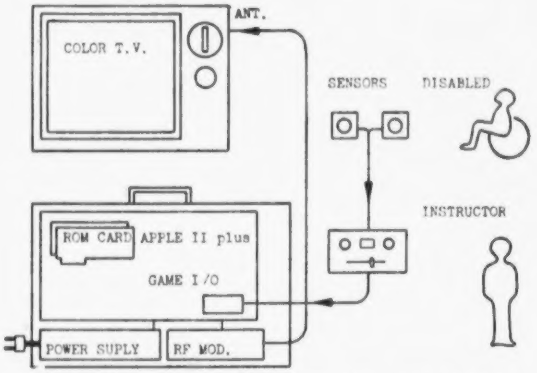


Fig.1 Block Diagram of the Simulator

After connecting the simulator and TV with the antenna cable, the program of the simulator starts automatically by only turning on power switch without any technical operations.

The ROM card supplies ten numbered programs from 0 to 9, and these are divided into three groups. The first group (No.0 to No.4) are to learn the sensor operation. The second group (No.5 to No.8) are to learn operational procedure of ECS. The third group (No.9) is simulative operation of ECS. A commercially avairable ECS, which we developed and is shown in Fig.3, is applied to the

hyogo r.c. ecs

Fig.2 The Portable Simulator of ECS

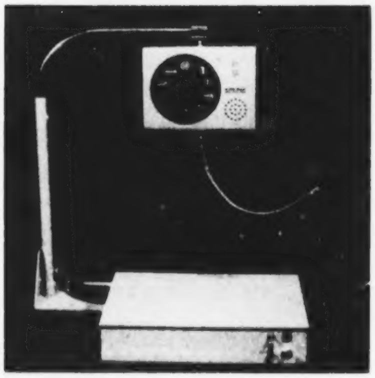


Fig.3 ECS used for the model

model of these programs. Especially in the program of No.9, a simulative shape of display unit of the ECS and simplified shapes of peripheral appliances are displayed on the screen of TV as shown in Fig.4. As the ECS has two types of operation modes that are one sensor mode and two sensors modes, these modes are prepared in each group of the programs. Before starting of each program, the menu shown in Fig.5 is displayed on the screen, and each program is able to be selected from the menu. At the end of each program, in the first group and the second group, the result of learning is displayed on the screen as the feature of numerical data.

The simulator was used to give the concept of ECS to medical staffs (occupational therapists and doctors) at first. Then the simulator was tested for nineteen severely disabled prospective operators to evaluate the avairability in clinical use. The nineteen subjects were eight spinal cord injuried, five cerebral palsied, four cerebral vascular diseased, and two head injuried. The ECS was also used by them to evaluate the simulative capability of the simulator in the program of No.9. In this test, an occupational therapist handled the simulator as one of medical staffs, without technical support from engineers. Fig.6 shows how the test is applied to a patient.

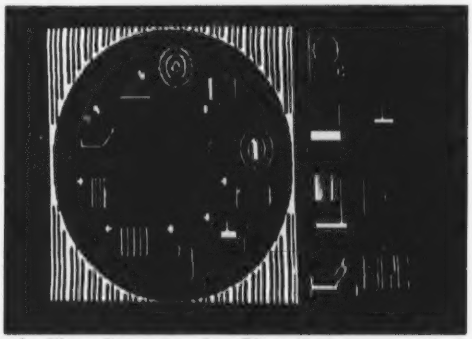
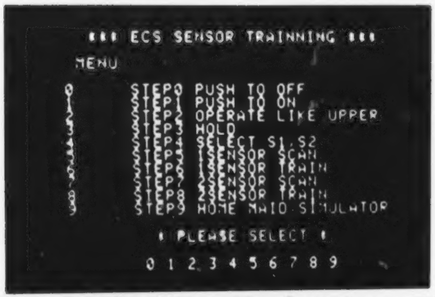


Fig.4 The Screen in The Program of No.9



```
*** ECS SENSOR TRAINNING ***
MENU
0      STEP0 PUSH TO OFF
1      STEP1 PUSH TO ON
2      STEP2 OPERATE LIKE UPPER
3      STEP3 HOLD
4      STEP4 SELECT S1.S2
5      STEP5 1SENSOR SCAN
6      STEP6 1SENSOR TRAIN
7      STEP7 2SENSOR SCAN
8      STEP8 2SENSOR TRAIN
9      STEP9 HOME MAID SIMULATOR
         * PLEASE SELECT *
       0 1 2 3 4 5 6 7 8 9
```

Fig.5 The Menu displayed on TV

Fig.6 Test appling to a patient

From the result of the test, following items were summarized.

(1) In the programs of the first group, the subjects learned basic sensor operation easily. However, in the programs of the second group, some subjects got confusing in understanding the content of each program ;application of basic sensor operation. As one of solutions on this problem, some assistive programs which contain easy application of sensor operation are necessary.

(2) In the program of third group, subjects controlled the shapes on the screen with a few mis-operation, as well as they controlled the ECS. Ratio of mis-operation/right-operation is nearly equal between the simulator and the ECS. The correlation coefficient is 0.69 (significant;p=1%).

(3) The occupational therapist handled the simulator without any technical difficulties in reason of simplified usage.

(4) Portability of the simulator is much effective to test a patient wherever he is.

(5) It is necessary to have the function to print each result of learning in the first group and the second group in order to use the simulator more clinically.

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A MOBILE ENVIRONMENTAL CONTROL SYSTEM USING CORDLESS TELEPHONE AND BSR TECHNOLOGY

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ABSTRACT - Designed for use by high level spinal cord injured persons, MECCA is a mobile environmental control system which utilizes the telemetry capabilities of a cordless telephone to operate BSR and more eloquent ECU accessories as well as the wireless phone functions.

RÉSUMÉ - Conçu à l'intention des personnes atteintes de maladies graves de la moelle épinière, le MECCA est un système de contrôle environnemental mobile qui utilise les capacités de commande à distance d'un téléphone sans cordon pour faire fonctionner les accessoires BSR et les accessoires ECU plus éloquents, ainsi que les fonctions du téléphone sans fil.

INTRODUCTION

Environmental Control Units (ECU's) have been instrumental in increasing the independence of those with extensive paralysis as well as those with other types of extreme motor impairment. An examination of the evolution of these devices reveals a tendency to add new features, as they are deemed desireable, by building on the design of the prior generation. This approach, while inexpensive from the standpoint of engineering costs, has imposed upon the more recent designs a compounding of progressively more encumbering constraints.

The first ECU's were operated from the bed and provided control of simple on/off functions (nurse call, light, fan, and a few others). Later telephone functions (substantially more eloquent) were designed and added to the list of items thru which one must scan. Whenever the phone rang, if you were on some other function, you would have to scan back to the phone. Other eloquent functions such as tunable radios, bed controls, and full-function tape recorders were added. At the same time the users wanted more lights, door locks, powered curtains,etc. The string of functions had become long and "jump to-" locations were added to patch a design which was proving a little bit cumbersome. High level "quads" were becoming mobile (workable wheelchair controls became available), so remote control links were added to provide control from the wheelchair to the existing ECU's. The BSR became a consumer item, hence it was utilized to yeild operation of AC outlets at some distance from the ECU. Superficially, this sounds like being where you want to be and controlling what you want to do. Actually, no matter what you want to control, you have to return to the ECU so that you can watch it scan thru the choices. (This constraint is not significantly affected whether the telemetry is ultrasonic, infrared, or radio). Finally, the engineer's enthusiam toward the combination of microprocessor and alphanumerics has resulted in a so called "menu" format. The happy result is a small flexible display; the unfortunate component is that there is no menu at all (only a textual listing of the present selection). The user initially uses a printed menu and eventually memorizes the system organization and its operational sequences. To require a printed menu is an inconvenience; while the eventual memorization is quite desireable.

The perspective has now shifted such that some ECU's should not be designed for operation from bed with a secondary consideration toward mobility. Rather, there is a need for ECU's which are designed to be effective in the more independent setting of mobility with secondary consideration toward bed stationed operation.

FUNCTIONAL DESCRIPTION

*Note- While there is a tendency to concentrate on technical (electronic) details, we consider it more useful to discuss notions underlying our approach and the features we determined to be most desireable for an effective design.

GENERAL APPROACH

The heart of the MECCA (Mobile Environment Control and Communication Accessory) is a slightly modified cordless telephone. The cordless phone must include the features of call tone and a modest directory function (9 or 10 numbers) within the hand-held portable. The packaging of the portable portion is removed as is its keypad and other manual inputs (switches). A microprocessor-based circuit is used to emulate the keypad cross-point closures, to transfer the phone from "standby" to "on", and to activate the call tone. A two-switch-controlled, select-and-activate sequence is used to operate the entire process, and a small, abbreviated, true menu-type display is included with the mobile portion. (A more detailed description of the operational format and the display configuration will be discussed later in the paper).

The base unit of the cordless phone is used in its commercial enclosure and plugs into an AC outlet and standard private phone line just as it normally would. The MECCA base unit, however, excercises supervision over the cordless phone base via an additional interconnecting cable. MECCA base examines the train of received dial pulses and determines whether further signals will be used for its own purposes or if the phone base will be allowed to place them on the phone line. Thus the first digit dialed after the receiver is "lifted" determines the nature of the function controlled by subsequent digits and/or call tone. The conventional on/off and more eloquent ECU accessories, BSR functions, "special", and supervisory functions are all handled within the format.

MECCA BASE

MECCA Base is a 17.5x11x5.5 inch (LxDxH) steel enclosure having a solid hardwood front which hinges down to expose connections for 3 special as well as 8 conventional (Prentke Romich style) ECU accessories. The ECU channels can be programmed in pairs to activate in momentary, toggling, or complementary latching modes. On the left side of the wooden front is a small, inlaid, dead-fronted display where the performance of various functions can be observed. Normally, this display is not used by the operator. Cables which plug into the ECU connections are routed thru a race which allows the cables to exit from the right rear of the box. On the back of the box there is an AC power cable and control connections for a BSR base unit and the phone base. There are also two live AC outlets and two controlled AC outlets which operates in parallel with two adjacent toggle-only ECU channels. Once a house code is set, there is a maximum of 16 BSR modules which can be controlled. Some of the ECU channels can be programmed so that, when activated, an approprate signal is sent to a BSR module. This has the effect of moving conventional ECU accessories away from the base without the need for long wires. (A special BSR to ECU adapter is required).

MECCA MOBILE

MECCA Mobile consists of a 10x10x 2.25 inch (WxHxD) enclosure which mounts on the back of the wheelchair, a 4x2x1.25 inch (HxWxD) display positioned in view of the operator, a suitable input, and a small speaker/microphone package which attaches to the wheelchair's headrest. Walkman or hands-free CB earphone/mike assemblies may be substituted for the headrest-mounted unit. MECCA Mobile requires two switch closures for operation, but also has an enable input so that it fits within the DU-IT quadrant/channel format.

THE BEDSIDE MODULE

When the operator is transferred from his wheelchair to his bed, it is useful that the functions provided thru MECCA continue to be available. The MECCA Mobile enclosure can be removed from its holster on the back of the chair, and plugged into a rechargeable, battery-powered Bedside Module. This module can be controlled by a tongue, puff-sip, or some other two-action switch. A user who is familiar with the operational format can control MECCA without a display, because the auditory feedback ("beeps", "ticks", and phone sounds) is completely descriptive of the control sequences. There is, however, a connection on the Bedside Module for an optional display.

OPERATION:

The onboard display is divided into three areas:

1. The Functions Menu-There are seven categories of function performed by MECCA (Phone, Directory, BSR, ECU, Special, BSR*, and Program Directory). One input, the select switch, will always allow the user to scan thru these functions (plus "OFF"). A "beep" accompanies each change of function. Stopping at a function "takes the phone off the hook", and automatically sends a dial pulse code (function access digit) which tells the base whether to be on the phone line or to be prepared for some other action.

2. The Status Prompts- These are four dead-fronted (not visible until illuminated) legends. They either flash (to remind the user what he must do next), or they are continuously lighted when the correct kind of action is being taken. The legends are: ACT-activate, DVC-device, OP-operation, and TN-tone.

3. A large Single Digit-This shows which BSR, ECU, Directory Number, Phone Digit, etc. is being selected. Each count of the digit is accompanied by a "tick". The second input switch (commonly called the "on/off" or "activate" switch) controls the counting of the digit or, in appropriate cases, the sounding of the tone (ECU accessories use the tone).

Operating MECCA is usually a three step sequence (answering the phone is one step, using the directory is two steps):

1. Using the select switch, the operator scans (accompanied by beeps) to the desired function (PHONE, ECU, BSR, etc.) MECCA Mobile automatically sends the function access digit.

2. Using the activate switch, he chooses the particular device in the group (accompanied by ticks). The DVC light which would have been flashing, then stays on.

3. Using the activate switch a second time, the user sets a BSR output level (i.e. lamp brightness) (accompanied by ticks), turns it on or off, controls an ECU accessory (MECCA sends a tone signal), etc. MECCA knows whether a tone or digit needs to be transmitted.

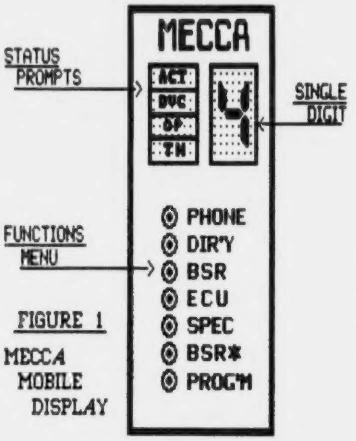

FIGURE 1

MECCA MOBILE DISPLAY

Since it is possible to distribute ECU accessories and BSR operated devices about the home, small labels are placed on the actual appliances to identify their correspondence to the system. Examples are: "BSR-5, "ECU-3", "TV On/Off-ECU-4", and "TV Channel-ECU-5". Even if the user chose to operate the TV thru the BSR, the label and the device's operation could remain the same.

MECCA HAND-HELD

If the portable portion of the cordless phone were not modified, the system (phone, directory, BSR, ECU, etc.) could still function (using MECCA base.) Its usefulness would be contingent upon the user's having sufficient manual dexterity to handle the phone. He would have to dial a function access digit before dialing the short sequences described in the previous section. All of the features of MECCA Base would be available to him.

SPECIAL SYSTEM FEATURES

The mobile portion of MECCA contains these special features:

1. Provisions so that input audio (from the telephone mike) can be used for other purposes (onboard megaphone, wireless microphone, etc.).

2. Connector-available clock, data, and strobe lines so that external serial output ports can be added to MECCA Mobile.

3. Provisions so that future modifications can yield a two-axis, proportionally-controlled selection format. This could more than triple the operating speed for many users. (This approach depends on a DU-IT system).

4. If the other ECU and BSR functions are not desired, MECCA can be operated without MECCA Base (a program switch change).

MECCA Base includes these features:

1. It provides for a new breed of ECU accessories ("Special") where sequences of dial pulses can directly determine the status of certain accessory functions (digitally tuned radios, TV's, etc.).

2. The base can intercept dial pulses and substitute dual tone so that special long distance services can be utilized. This is under the user's control.

3. The base can display the numbers in the directory (without actually dialing them). This is under user's control.

4. Rechargeable batteries assure operation during power failure.

5. MECCA Base remembers power failures and when the user begins to use it, MECCA alerts him to the prior interruption. This is in case a power interruption might affect some previous setting.

6. Connections are provided for a large lead-acid battery permitting extended power failure operation. (BSR functions will not be available during power failure).

7. Complementary ECU pairs make it possible for the operator to send one signal that tells the door to be locked and a different signal to unlock it (or similar functions).

CONCLUSION:

MECCA's design is the result of many years of contending with far less than ideal circumstances when trying to unite conventional ECU's with wheelchair control systems. Often the ECU's features did not match the needs of those who became mobile. MECCA's design does indeed focus on the needs of the mobile, high level, spinal cord injured person at the expense of some fixed location features. There is a component of inconvenience in having to move MECCA Mobile from the wheelchair to the Bedside Module. This is over-shawdowed by the independence from the base in the mobile phase of utilization. MECCA represents a limited "be-where-you-want-to-be, control-what-you-want-to-do" solution for the mobile person with extreme motor impairment.

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SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 27

COMMUNICATION AIDS II - DEVICES/

AIDES À LA COMMUNICATION II - DISPOSITIFS

DEVELOPMENT OF A SET OF INTERNATIONAL COMMUNICATION AIDS COMPATIBILITY STANDARDS PROPOSALS (ICAC STDS)

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ABSTRACT - The paper introduces the development of a set of proposed compatibility standards for electrical communication aid devices. These compatibility standards proposals are primarily aimed at electrical communication aid devices for conversation, writing and computer access. The paper briefly describes each of the standards being developed.

RÉSUMÉ - L'objet de cette communication est d'exposer l'élaboration d'un ensemble de normes de compatibilité, qui a été proposé pour les aides de communication électriques. Ces propositions de norme visent principalement les aides de communication servant à la conversation, à l'écriture et à la communication avec un ordinateur. Chacune des normes en cours d'élaboration est décrite succinctement.

The TRACE Center is developing a set of proposed compatibility standards for electrical communication aid devices for conversation, writing, and computer access in conjunction with a group of interested manufacturers, clinicians, and researchers. Our goal is to reach a consensus on compatibility standards proposals and then get these proposals formally adopted by national and international standards organizations.

Purposes of Compatibility Standards

Many of the switches and controls used to operate electronic communication aids are functionally identical, and should be interchangeable. However, different manufacturers have selected different connectors, electrical formats, and logical formats. This makes it difficult for clinicians and users of aids to connect controls to an aid from a different manufacturer to configure a system appropriate to the person. It also reduces the market for these devices and forces manufacturers to provide the entire aid system.

The purposes of the proposed compatibility standards are:

1) to help provide appropriate and effective augmentative communication systems to anyone who needs them
2) by allowing electronically naive users, supporting persons, and service delivery persons to configure aid systems from components from different manufacturers
3) by allowing functionally appropriate devices from any manufacturer to be interconnectable and compatible with devices from any other manufacturer.

During the past year we have decided that compatibility for communication aids will be facilitated by the development of separate standards for functionally distinct situations. This makes each separate standard simpler and easier to implement and will make it easier to get the necessary consensus, which is the main test of a compatibility standard. We are currently working on the following compatibility standards proposals:

1) SET Compatibility Standard (Simple Electrical Transducer Compatibility Standard proposal)

Purpose: The SET Compatibility Standard is designed to provide for compatibility of simple electrical transducers and communication aids from different manufacturers .

Scope: The SET Compatibility Standard is meant to cover the connection between simple electrical transducers (switches, potentiometers, and rheostats) and communication aids. More sophisticated transducers such as EMG transducers can be used with the SET Compatibility Standard if they emulate one of the simple transducers.

2. SETSC Compatibility Standard (SET Serial Conversion Compatibility Standard proposal)

Purpose: The purpose of the SETSC Compatibility Standard is to provide a standard way to use adaptive SET controls with commercial portable computers through a standard RS-232C input port. This is done by providing a standard serial data format for transmitting simple electrical transducer information. This allows standard SET to RS-232C converters to be developed and allows standard software routines for processing input.

Scope: The SETSC Compatibility Standard proposal allows information from switches and pots to be transmitted on a single RS-232C serial channel simultaneously. This standard is also used for sending position information from long-range light pens and other devices that send X-Y coordinates.

3) ISA Compatibility Standard (Input Selection Array Compatibility Standard proposal)

Purpose: The purpose of the ISA Compatibility Standard is to provide for compatibility between input selection array transducers (such as large array keyboards) and communication aids.

Scope: The ISA Compatibility Standard is meant to cover Input Selection Array devices such as selection array keyboards (keyboards that are meant for one-at-a-time selection by location), scanning panels that can output a discrete selection after interacting with the user through a simple switch, and other devices that allow the user to make a single selection at a time from a displayed array of selections.

4. KEI Compatibility Standard (Keyboard Emulator Input Compatibility Standard proposal)

Purpose: The purpose of the Keyboard Emulator Input Compatibility Standard proposal is to provide a standard electrical and data input format for keyboard emulators. This will make it possible for an aid that can produce the Keyboard Emulator Input Compatibility Standard format to work with any standard keyboard emulator and thus work with any computer that has a standard keyboard emulator installed.

Scope: The KEI Compatibility Standard proposal is meant to cover the connection between a communication aid and the keyboard emulator for a computer running standard software. Keyboard emulators are devices designed to accept electronic data input and to introduce that data into a computer running standard software in such a way that it is indistinguishable from data input on the keyboard. The form of the data input to the keyboard emulator is the focus of the KEI Compatibility Standard proposal (the output of the keyboard emulator will always be specific to a particular computer and therefore not standardizable).

5. KEIMC Compatibility Standard (Keyboard Emulator Input Morse Code Compatibility Standard proposal)

Purpose: The purpose of the Keyboard Emulator Input Morse Code Compatibility Standard is to allow people using a three state sequential code (i.e. International Morse) to effectively communicate and to access computers.

Scope: The KEIMC Compatibility Standard is a superset of international Morse code. Using a three state sequential code it will produce the complete ASCII character set, common non ASCII keys such as arrow keys, and the special KEI functions such as "HOLD" for emulating key combinations.

6. SBC Compatibility Standard (Subsystem Bidirectional Communication Compatibility Standard proposal)

Purpose: The purpose of the SBC Compatibility Standard is to make it possible to design aids in a modular fashion to reduce the cost of the aid system, increase the lifetime of the aid, make the system more tailorable to the needs of the user, and reduce the skills required to properly specify, apply, install, and maintain the system.

Scope: The SBC Compatibility Standard is meant to cover bidirectional communications between communication aid subsystems such as a portable main processor, input display, output display, printer, voice output subsystem, environmental controller, modem, and wheelchair controller.

We hope that anyone developing or manufacturing devices covered by these proposals will contact us about them.

THE PRACTICAL APPLICATION OF PORTABLE COMPUTERS AS AUGMENTATIVE COMMUNICATION AIDS

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ABSTRACT - This paper discusses implementing communication aids on portable personnel computers. An Epson HX/20-based direct selection system and a Radio Shack Model 100-based scanning system have been developed. Clinical evaluation is currently being conducted on prototypes.

RÉSUMÉ - Cette communication traite de l'utilisation d'aides à la communication avec des ordinateurs individuels portatifs. Un système à choix direct basé sur un Epson HX/20 et un système à balayage basé sur un Radio Shack Model 100 ont été mis au point. Des prototypes font actuellement l'objet d'une évaluation clinique.

INTRODUCTION

The development of lower cost augmentative communication aids has been pursued through the use of personal computer based systems (1),(2). These systems are potentially less expensive because personal computers are produced in much greater quantities than single purpose communication aids. The advent of portable personal computers has further facilitated the development of portable aids.

The goal of this project is to utilize portable computers and "off the shelf" peripherals (e.g., text to speech synthesizers) to produce aids that will be more affordable for the disabled individual. This paper will discuss two implementations of portable computers, as well as some general design issues.

DIRECT SELECTION / EPSON HX-20

The implementation of a direct selection strategy utilizes an Epson HX-20, a Houston Instruments digitizing tablet, and an Echo GP speech synthesizer. Choices from an array of 144 (1" square) language units and commands are selected with an electromagnetic pointer. The Epson translates pointer position (.01" resolution) into user selection. Resident features include multiple levels, message storage, and user alterable vocabulary.

Software has been implemented in BASIC with time critical procedures implemented in 6301 machine language. These include RS-232 read, formula translation of digitizer coordinate, and selection identification.

Clinical evaluation of the prototype system is being performed with a 22 year old individual with cerebral palsy. The components are packaged in a two piece ABS housing. The Epson computer, Echo speech synthesizer, and batteries are contained in a case that normally resides in the rear of the wheelchair. The digitizing tablet is mounted on a Prentke Romich wheelchair mounting system, along with a speaker. The patient is shown (figure 1) operating the device.

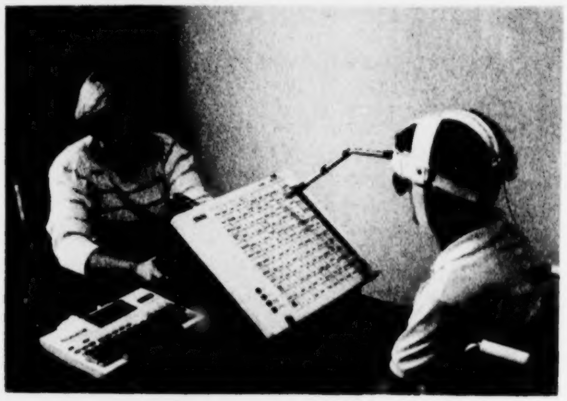

Figure 1 Direct Selection Using the Epson HX-20

SCANNING / RADIO SHACK MODEL 100

The implementation of row-column scanning utilizes a Radio Shack Model 100 portable computer and an Intex-Talker speech synthesizer. A single switch is connected to the bar code reader input of the Model 100. The primary level consists of the alphabet (arranged in the same efficient order as the Tufts Interactive Communicator (3)), numbers, punctuation, and commands. Additional levels contain words, sentences, and non-alphanumeric ASCII characters (e.g., CTRL-C). The user has control of the vocabulary as well as scan rate.

The clinical prototype is being used by a 20 year old individual with cerebral palsy. The components are configured in a two piece package; the Model 100 and speaker are mounted in view of the user, and the Intex-Talker and batteries are mounted on the back of the wheelchair. An RS-232 interface is provided for connection to a printer or computer system.

PACKAGING CONSIDERATIONS

Demasco and Foulds introduced the concept of portable computer based communication (2). Software was developed to demonstrate scanning and direct selection. The work that has followed represents the efforts to produce clinically usable systems

One of the most important issues that must be addressed is packaging of the components that comprise the communication aid. This physical package represents the major component of the system that is not mass-produced. The following specifications are suggested and are being incorporated into case revisions:

1. Parts of the components that are used should be accessible. For example, the keyboard although not neccesarily used by the patient, will be used to load programs (this can be done by a family member or clinician).
2. The components and cabling should be adequately protected. This and the previous constraint can sometimes present difficulties. For example, the reset button and the RS-232 connector are adjacent on the Model 100. Protecting the connector and making the reset accessible requires a more complex design.
3. The size and weight of the package should be minimized (the larger the device, the more likely that it will act as a wheelchair bumper). One approach is to distribute the components into a two piece package.
4. Modularity of package design will allow for different implementations and components without excessive retooling.

PRODUCT EVOLUTION

The portable computer marketplace is rapidly changing. The Panasonic Hand Held Computer has been rendered obsolete by the Epson HX-20. The Radio Shack Model 100 introduced a much larger display, making it more suitable for scanning than the Epson HX-20 (it is debatable whether the Model 100 makes the HX-20 obsolete in general). Although the market seems to be settling, the rehabilitation engineer must develop designs that will adapt to the evolving market (e.g., 16 bit systems are inevitable). This can be accomplished through modular design and portable software.

CONCLUSION

The evaluation of the current prototypes will result in a second generation design. After a second evaluation is performed, the REC will transfer the technology to the manufacturing community. Research will continue to expand the capabilities of these systems. This will include additional interfaces (e.g., joysticks) and more efficient communication strategies (e.g., 3-dimensional scanning).

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STENOTYPE SHORTHAND AND SPEECH SYNTHESIS IN VOCAL PROSTHESIS FOR THE DEXTEROUS SPEECH IMPAIRED

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ABSTRACT - This paper describes the application of stenotype machine shorthand and speech synthesis in a keyboard-to-speech vocal prosthesis. The system allows a dexterous stenotypist to "speak" with an unlimited vocabulary at up to verbatim speech rates.

RÉSUMÉ - La présente communication explique comment on a appliqué la sténographie d'une machine sténotype et la synthèse de la parole à la réalisation d'une prothèse de type "clavier parlant". Un sténographe habile a la possibilité grâce à ce système de "parler" avec un vocabulaire illimité, à une vitesse égale à la vitesse maximale de transcription mot à mot.

Some recent developments in communication aids for the speech impaired have featured synthetic speech output (1). Like most communication aids, however, they suffer from the problem of data rate restriction, where information transfer is much slower than between able-bodied persons. Typical conversational speech rates are between 150 and 180 words per minute, whereas a good typist can only encode at 60 to 80 words per minute. A dexterous person can therefore communicate via conventional typewriter keyboard at only about one third normal speaking rate. Motor dysfunction, however, reduces the attainable typing rate. Synthetic speech output may be derived from typed information, but conversation by this means is restricted by the low typing rate. A number of systems have been developed to improve the effective typing rate, e.g. ergonomic keyboards, stored word lists (2), etc., but none have achieved sufficient improvement to allow unrestricted conversation at normal rates.

Nevertheless, a mechanical keyboard method for encoding speech at verbatim rates has existed for many years - stenotype machine shorthand. Stenotype keyboard systems are phonetically based. A spoken word is analysed into its constituent syllables. Each syllable is then typed, with a coded quasi-phonetic spelling, in one stroke (called a "chord") of the keyboard. This allows a significant speed advantage over conventional keyboard operation, hence a trained stenographer can type at verbatim speech rates. Trained stenographers can therefore record speech via keyboard without restriction of either speed or vocabulary. The speech is recorded in a coded phonetic form which the stenographer normally translates into a verbatim record at a later date.

Stenotype is the generic term for chord-keyboard shorthand typing. Several stenotype systems exist, including the British Palantype, the French Grandjean, and the American Stenograph systems. The Stenograph machine was introduced in the early 1900s, and has a total of 23 keys on its keyboard. Because there are so few keys, a complex coding convention is used to represent the "missing" alphabetic characters. The Grandjean machine has fewer keys than the Stenograph, and there is somewhat more ambiguity in its coding practice, particularly for final consonants. The Palantype machine was developed from the Grandjean machine to make it more suitable for use with the English language. It has 29 keys, and its coding convention is much more strictly phonetic than those of the other two machines.

A number of automatic transcription systems have been developed to translate stenotype data into conventional orthography for office applications. The authors have participated in the development of real-time speech transcription equipment for the hearing impaired based upon stenotype shorthand keyboards. The Palantype, Grandjean and Stenograph systems have all been investigated in this context (3,4). The transcription systems operate in real-time, producing output text which is typically 95% correct orthography. Factors such as stenotypist error prevent 100% accuracy, so transcription features are incorporated which ensure approximately correct and readable orthography. These transcription systems are effective speech-to-text translation systems, and fully operational Palantype systems have been used by deaf people for more than six years. This paper, however, considers another application for stenotype transcription, this time in vocal prosthesis for the dexterous speech impaired.

Transcribed stenotype text can be relayed, in real-time, to a phoneme-based synthesiser equipped with a text-to-speech translation program. This will realise a real-time, natural speech rate, keyboard-to-synthesiser vocal prosthesis. Such a system could be used, after a suitable period of training, by a dexterous speech impaired person, with the distinct advantages of unrestricted vocabulary and, ultimately, natural speech rate.

The speech-to-text-to-speech approach requires two translation processes to be performed - stenotype syllables to conventional orthography, and orthography to synthetic phonemes. Neither translation process is perfect, however, and inadequacies in each will compound to reduce output speech quality. Both translation processes require significantly large microcomputer memories, translation quality being to some extent a function of memory size. Both translations can be eliminated, however, if it is recognised that one translation is the inverse of the other. Stenotype speech coding is essentially phonetic, and unlimited vocabulary speech synthesisers are generally based on phoneme-to-speech conversion. The translation processes can therefore be replaced by a much more compact stenotype-to-phoneme conversion algorithm. An intermediate solution, which is also very effective, is to transliterate stenotype keyboard strokes into quasi-orthographic syllables, and relay these to a text-to-speech converter. Hence one or both of the imperfect translation processes can be eliminated to produce a simpler, more reliable and more compact keyboard-to-speech converter.

Prototype microcomputer-based stenotype-to-speech systems have been developed for Palantype and Stenograph. The alternative processing strategies described above have been realised and assessed in operation. The perceived speech quality achieved by any one of these processes is similar to that produced when the correct orthography for the same text is passed through the full text-to-speech translation system. This indicates that the stenotype-to-text and text-to-speech translations are not necessary, and in consequence a much simpler and smaller system can be produced.

The user of this system must have good manual dexterity and language skills. A period of keyboard training will be required, consisting of instruction and practice. While conventional stenotypists must achieve verbatim typing rates, however, a speech impaired user can start to use the system at slow equivalent speech rates, progressing with experience to faster and more realistic "speech". The speech impaired user may eventually put this skill into commercial practice and become a working stenotypist, achieving employment opportunity as well as self-expression. This advantage is also available to the sight-impaired, who can use speech output to assist them to train and work as stenotypists. This was previously impossible because the output from a conventional stenotype machine is a roll of printed paper or a magnetic computer tape, neither of which can be directly reviewed by those with impaired sight. Speech output can also assist the able-bodied during stenotype training and practice.

While a stenotype-phoneme-speech system has the advantages of simplicity and small computer memory requirement, and hence portability and economy, the system could be equipped with a small dictionary of common words to allow the stenotypist to use abbreviations. This would reduce the typing work load and increase effective typing speed without detrimental effect on the cost or the size of the equipment. Any word not present in the abbreviation dictionary would have to be stenotyped in full. Experience with the Palantype system in particular proves that it is quite possible to stenotype verbatim speech without using any abbreviation.

A prototype system has been developed which shows that a stenotype transcription system can be used to drive a phoneme-based speech synthesiser. This provides a natural speech rate vocal prosthesis for the dexterous speech impaired.

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LA TABLE DE COMMUNICATION "SIMPLICOM"

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RÉSUMÉ - Cette table de communication électronique fut conçue pour des personnes non-verbales présentant des difficultés sévères de pointage. La communication se fait par images ou symboles déjà programmés. Un micro-ordinateur permet de pré-programmer son message qui apparaît sur un double affichage lumineux. Son volume réduit, son design esthétique pouvant s'adapter à tout fauteuil roulant et sa simplicité de fonctionnement permet à son utilisateur de mieux s'intégrer.

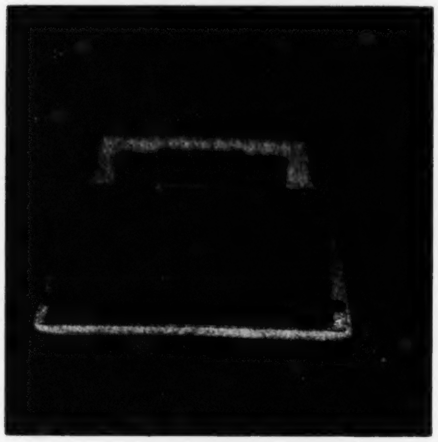
ABSTRACT - This electronic board of communication was made to help non-speaking persons showing severe difficulties of pointing. The communication is done through pictures and symbols already programmed. A microcomputer allows people to preprogram any message which appears on a double illuminated board. Its reduced size, its aesthetic design fitting to any wheelchair and also the easiness to operate it permit a better self-integration to the user.

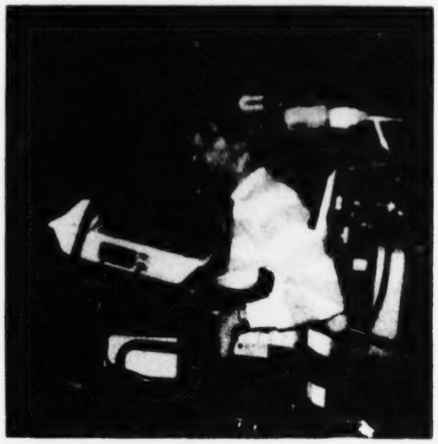
Au Centre François-Charon comme dans d'autres centres au Québec, les limites des personnes handicapées sont souvent reliées à leur potentiel d'utilisation d'un système de communication non-verbale. On se heurte souvent à des difficultés de pointage très sévères reliées à des difficultés physiques. Pour tenter de résoudre ces difficultés, l'équipe s'est tournée vers des aides électroniques existantes sur le marché mais aucune ne répondait vraiment à nos attentes, trop dispendieuses,en anglais et peu adaptables aux fauteuils roulants. Cette situation nous a amené à concevoir ce projet de table de communication "Simplicom" pour répondre aux besoins de communication de notre clientèle adulte.

Le deuxième prototype "Simplicom" a été conçu et réalisé à l'été 1983, à partir des observations et recommandations faites lors de l'évaluation du premier prototype dans quatre (4) centres de réadaptation et d'éducation soit: Cardinal-Villeneuve et François-Charon à Québec, Victor-Doré et Joseph-Charbonneau à Montréal.

La table "Simplicom" est caractérisée par un volume réduit et par un design qui s'adaptent parfaitement aux fauteuils roulants manuels et motorisés.

Plusieurs adaptations peuvent y être couplées pour suppléer aux difficultés de pointage. Ainsi, toute personne qui est capable d'un bon contrôle de la tête ou toutes autres parties du corps pourra utiliser ce moyen de communication.





Sa simplicité de manipulation facilite les apprentissages et améliore la communication des personnes de tout âge, privées de l'usage de la parole, telles les personnes paralytiques cérébrales.

La table "Simplicom" permet de communiquer soit par des images ou symboles standardisés imprimés sur acétate formant un tableau de 352 cases dont 296 mots usuels de base, 26 lettres de l'alphabet et 10 chiffres déjà programmés, ce qui réduit d'autant la tâche de programmation. Le tableau d'images peut servir à l'enseignement du pré-Bliss chez l'enfant. A l'école, elle joue un rôle didactique dans l'apprentissage de la lecture et de l'écriture. Pour l'enfant autant que pour l'adulte handicapé, cette table demeure un outil de communication dans les contacts quotidiens.

L'alpha-numérique affiche le mot ou les lettres sélectionnées sur la table qui devient ainsi un stimulant à l'apprentissage de la lecture et de l'écriture. Cette possibilité d'écriture permet d'ajouter des mots spécifiques selon les besoins de l'utilisateur, lui donnant ainsi un vocabulaire plus personnalisé qui ne se limite pas aux 296 mots déjà programmés. Cette propriété de l'alphanumérique double, qui affiche simultanément le message, favorise la communication avec son interlocuteur en lui permettant la lecture immédiate de celui-ci et d'y répondre rapidement.

Un ordinateur permet à l'utilisateur de pré-programmer son message et l'effet spécial "chaise roulante" de se déplacer et de retransmettre lorsque désiré son message qui apparaît sur l'affichage lumineux.

Ainsi utilisée, la table "Simplicom" augmente l'autonomie de communication de l'usager de tout âge et lui permet de s'intégrer dans sa famille, en foyer de groupe et dans les milieux communautaires. En effet, en plus d'un design recherché au plan esthétique, elle a été conçue pour affronter les intempéries de nos hivers tout en utilisant une mini-batterie de 12 volts ajoutée au fauteuil manuel ou celle du fauteuil roulant motorisé.

Ce projet de recherche a été financé par l'Association de Paralysie Cérébrale de Québec, la Fondation François-Charon et le Centre François-Charon de Québec.

A PORTABLE COMPUTER-BASED WRITING, CONVERSATION AND COMPUTER ACCESS AID FOR SEVERELY MOTOR IMPAIRED INDIVIDUALS

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ABSTRACT - This portable communication aid is designed to provide basic language capabilities to severely motored impaired individuals in educational and vocational situations. The aid can be used for writing, conversation, and, with the use of keyboard emulators, access to standard computers.

RÉSUMÉ - L'aide de communication portatif que voici a été conçu afin d'offrir des fonctions de langage de base à des personnes affligées de troubles moteurs sévères, exploitables à l'école ou à leur travail. Ils peuvent s'en servir pour écrire, converser, ou communiquer avec des ordinateurs standard par l'intermédiaire d'émulateurs de clavier.

INTRODUCTION

Three of the major communication problems for non-vocal severely motored impaired individuals are conversation, writing and access to standard computers. The ability to converse and write is necessary for a child to enable him or her to receive a education comparable to his non-motor impaired peers in the same classroom. Conversation is important for developing expression skills, asking and answering questions, learning social interaction, and participating in classroom activities and discussions.

Writing has often fallen into the shadow of conversation, and been a secondary consideration in language intervention. This concept is changing, though, (Vanderheiden, 1983) as the importance of writing in education becomes clear, and handicapped children develop better language skills. Writing is required for a variety of normal classroom activities such as independent study, homework, testing, workbooks and the development of expressive writing skills.

Computers are being used in schools for two purposes. The first is to introduce students on how to operate and program computers, and the second is to facilitate the learning of a particular subject such as math, English, and science. Severely handicapped children also need to participate in these uses of computers. To do this they need to be able to use the same computers and programs as the other children in the classroom, even though they may not be able to type on the standard keyboard (Vanderheiden, 1982).

FUNCTIONAL DESCRIPTION

The EWCCAA (Electronic Writing, Conversation and Computer Access Aid) is being designed to meet these three basic communication needs. This aid has three separate parts: an input interface, amplification of selections, and the output function.

The EWCCAA is currently based on a EPSON HX-20 portable lap-held computer, but can be adapted to other computers as well (DeMasco and Foulds, 1982). The HX-20 has many of the features needed in portable communication aids. The HX-20 has rechargable batteries that provide continuous operation for up to 50 hrs. The 4 x 20 character LCD display provides a means for providing a correctable piece of "paper" to meet basic writing needs. A 24 column printer is used for generating a permanent copy of text the user has entered. A 50K micro-cassette drive provides a means of storing and retrieving text and backing up a users abbreviation expansion vocabulary.

Input Interface

The input interface is the part of the aid that the user interacts with to control the aid. Initially there will be three input techniques which can be used with the aid: the existing keyboard, external keyboards (large and small), and morse code. The existing keyboard technique uses the built-in keyboard of the HX-20. The keyboard is converted to a single-finger keyboard so that the user isn't required to hold down two keys simultaneously, which is normally necessary for generating shifted or control characters on standard keyboards.

The external keyboard (Graystone, 1982) is also a one-finger keyboard, similar in operation to the built-in keyboard. The external keyboard is a completely independent self-contained keyboard with a serial output, and typically has larger or smaller keys than the standard keyboard. These smaller or larger keyboards can be more selection information is formatted with the ISA (Input Selection Array) Standard for coding key selection information into a serial data format (Rodgers and Gunderson, 1984). The ISA standard is part of the International Communication Aids Compatibility Standard (ICAC).

The morse code input is a two switch auto keying input technique similar to traditional morse code. The keying patterns have been enhanced to allow the generation of the entire ASCII character set (the ASCII character set is the standard set of characters used with computers).

Amplification

The amplification part of the aid increases the effective selection rate of the user. The particular amplification technique used in the EWCCAA is Speedkey. Speedkey is a very general purpose technique which converts a preprogrammed sequence of characters into another sequence of characters. The conversion of the character string is automatic, eliminating the need for an expand key found on some systems which thus require an extra user selection. An example of a speedkey entry would be using the character string "dfn" to represent the word "definition ". As soon as the characters "dfn" are selected the characters would be replaced by the expansion "definition ". The vocabulary items are completely programmable by the user to meet their particular communication requirements.

Speedkey can be used to develop both abbreviation expansion and level techniques. The level system can be implemented with a prefix function which attaches to the beginning of each character sequence a prefix for the purpose of looking up expansions. The prefix is functionally the same as changing levels because only abbreviations starting with the prefix can be selected.

Output Functions

There are five major output functions: worksheet, notebook, keyboard emulator, printer and speech synthesizer. The worksheet function is the user's pencil and paper and allows the user to enter and edit text. The worksheet has two pages of text, with each page holding approximately 2000 characters. The notebook provides a means to store and retrieve single worksheet pages of text. The page is stored on the cassette tape unit of the Epson and a approximately 20 pages of text can be stored per tape.

The EWCCAA will also be able to drive keyboard emulators using the KEI (Keyboard Emulator Input) standard which is a part of the ICAC. The keyboard emulator can be used directly with the output of speedkey or from the worksheet by transfering the worksheet text to the emulator.

The printer and the speech synthesizer functions can also be used directly with speed key, or from the text on worksheet. The printer and speech synthesizer have slightly different control routines because of their different functions and uses.

CONCLUSION

The objective of this project is to provide a child or adult with a means to participate in normal classroom and vocational situations. The EWCCAA provides the individual with a means to perform the basic communication functions required in both these settings along with the ability to work independently. By using only standard hardware, it is possible to provide these functions for a half to a third the cost normally associated with this type of aid, and move the aid to market in months rather than years.

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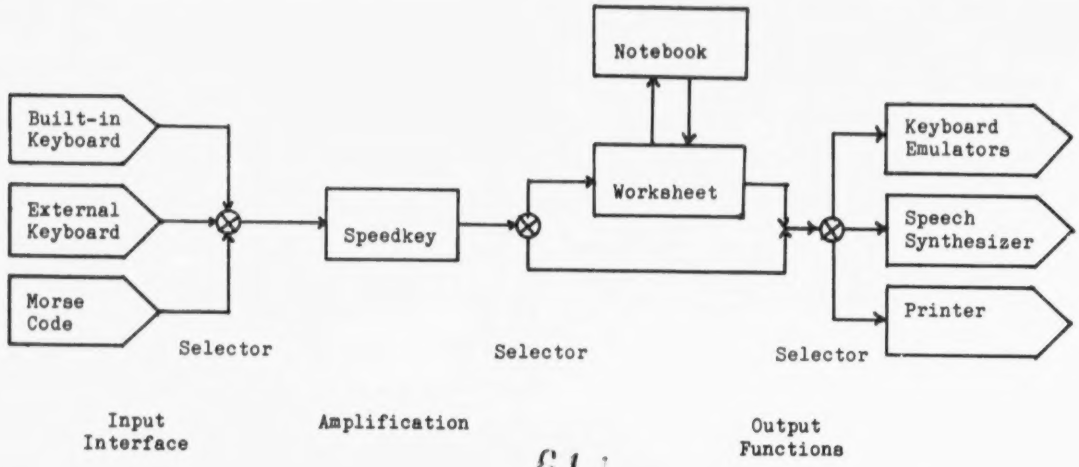

SCIENTIFIC SESSION/SÉANCE SCIENTIFIQUE 28

GAIT STUDIES/
ÉTUDES DE LA DÉMARCHE

PREOPERATIVE AND POSTOPERATIVE GAIT ASSESSMENTS AS A GUIDE IN PLANNING TENDON TRANSFERS ABOUT THE ANKLE JOINT IN CHILDREN WITH CEREBRAL PALSY

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ABSTRACT - Pre- and post-operative clinical and gait laboratory measurements are being used as a guide in planning surgery about the ankle joint and assessing surgical outcome thus providing a basis for explaining success or failure.

RÉSUMÉ - Des mesures pré- et post-opératoires en clinique et des mesures de démarche en laboratoire servent à orienter la planification de la chirurgie de l'articulation de la cheville et à évaluer les résultats de la chirurgie de façon à expliquer un succès ou un échec.

Introduction

In normal walking, each muscle contracts at an appropriate time and the muscle moves through correct excursions to produce joint motions. In cerebral palsy, both the timing and strength of muscle contractions may be incorrect. Many ambulant children with cerebral palsy undergo surgery for the correction of gait problems. The surgeon has a repertoire of procedures to choose from that are aimed at stabilizing posture and balancing deforming forces which act about joints. Such procedures include tendon lengthenings, transfers and tenotomies. Determination of which procedure to select depends upon a knowledge of what muscles are acting when. The traditional examination of a child lying down and walking back and forth (observational gait analysis) provides an incomplete description of gait from which the patterns of muscle activities cannot be confidently predicted.

The introduction of dynamic electromyography has led to corrective surgery based upon the phasic activities of muscles[1-4] since it has been demonstrated that muscles whose tendons are transferred generally retain their preoperative phasic activity[5,6].

Determination of surgical outcome has remained relatively subjective. Traditionally, assessment has been based on estimations of static joint ranges of movement, muscle strength, observed changes in gait, and independence at home and school. As urged by Winter (1976)[7], gait laboratories should be able to considerably augment clinical assessments by providing objective kinetic, kinematic and electromyographical measurements of gait pre- and postoperatively.

The study described in this paper was undertaken with the following objectives in mind: (i) To use dynamic electromyography as a major guide in planning tendon transfers about the ankle joint; (ii) To assess the outcome of such surgical procedures by clinical and gait laboratory measurements; (iii) To use gait laboratory measurements to assist in determining reasons for surgical success or failure.

This approach should lead to the definition of more objective criteria for surgical success or failure thus aiding in the development of more appropriate surgical answers.

Clinical Material

Twenty-three children have been seen preoperatively regarding surgery related to the ankle joint. Of these, 17 have since undergone surgery and 4 have yet to have surgery. In two cases, surgery at the ankle was contraindicated. The children range in age from 3 to 16 years (mean of 8.9 years). Nine of the children had spastic diplegia (5 with equinovarus, 1 with equinovalgus, 2 with equinus and 1 with a severe toe-flexor-deformity); 7 had spastic hemiplegia (4 with equinovarus, 2 with equinus and 1 plano-valgus); 2 were spastic quadriplegics (1 equinovalgus and 1 valgus); 2 had spina bifida (1 cavovarus and 1 calcaneous): 1 had a head injury with drop foot; and 1 had a tethered cord with cavovarus feet.

Assessments

Detailed clinical and gait laboratory assessments are undertaken prior to surgery, and at 4, 8 and 12 months post-surgery. The clinical evaluation incorporates a parent's questionnaire, measurement of active and passive ranges-of-motion, and a gross motor assessment.

Gait assessments consist of simultaneous electromyographic, footswitch, ground reaction forces and positional data recorded during walking. Monitoring of EMG signals is accomplished with the aid of surface or fine-wire electrodes.

Data displayed versus time include EMG, footswitch, joint angles in the sagittal plane, the degree of rotation of the foot in the transverse plane, transverse projections of all marker tradjectories, and joint moments. In addition, temporal information is calculated from footswitch and average velocity measurements. The method of Simon et al (1978) has been used in which abnormal findings are listed for each assessment and changes between assessments are then noted.

Results

At this stage of the study it is only possible to assess the influence of the preoperative gait assessments in terms of how they influenced the selection of the surgical procedures performed. In 5 of the 23 cases, technical difficulties with the fine-wire electrode system precluded decision-making based upon the gait study itself. In 8 cases, the preoperative assessments confirmed the surgeon's initial decision; in 2 cases, the initial decision was reversed; in 7 cases, the gait study resolved the surgeons' dilemma with regards to the operation to be performed (in 2 of these, the decision was not to perform surgery); and in 1 case, surgery was performed when this had not been recommended.

The following case demonstrates the analysis of results to date:

Case 4 is a 13-year-old female with spastic diplegia who was referred because of an increasingly rigid gait and frequent falling. She had undergone bilateral lengthening of the tendo-achilles 7 years previously. The surgeon queried whether the tibialis posterior on the left side should be lengthened or transferred.

From the gait study, the peroneus longus was found to be active from mid-swing to the end of stance whereas the tibialis posterior acted inconsistently. Since tibialis posterior was not functioning satisfactorily, lengthening of the tendon was recommended. Roentgenograms also showed that the left hip was beginning to sublux and a decision was made to release the hamstrings and adductors.

Foot-floor contact patterns changed from footflat-toe preoperatively to heel-footflat-toe 4-months postoperatively. Preoperatively, the ankle could be brought to plantigrade with the knee flexed. Postoperatively, the ankle could be brought to 10° of dorsiflexion. However the range of foot movement in the sagittal plane did not change following surgery. A marked change was noted in the transverse plane as illustrated in Figure 1. Overhead transverse projections of joint trajectories as shown in Figure 2 indicate that the excessive lateral movement seen during the swing phase of gait has now considerably improved showing greater stability. Symmetry as measured by the ratio of left-to-right stance-to-swing ratios improved from 2.14 to 1.16.

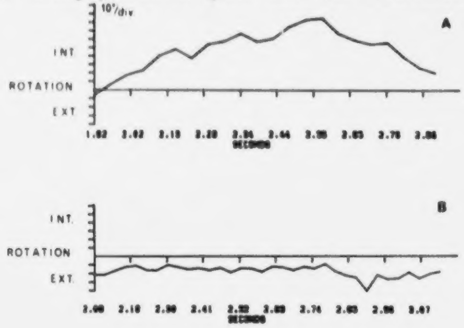

Figure 1: Rotation of foot in transverse plane.
A:-before surgery B:-4 months post-surgery.

From a subjective viewing of the video records and from the parent's questionnaires, preoperatively the subject had an asymmetrical jerky gait with extreme varus of the foot and internal rotation of the lower leg. She walked on her toes and often tripped and fell. Postoperatively, her gait is much smoother with less internal rotation. She has less arm movement and the frequency of tripping and falling has considerably diminished.

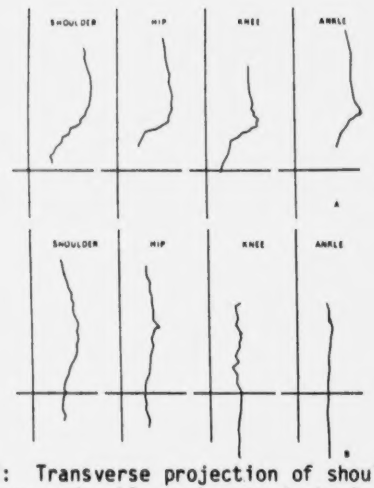

Figure 2: Transverse projection of shoulder, hip, knee and ankle marker trajectories.
A: Pre-; B: Post-surgery. Scale: 10 cm/div.

Preliminary estimations of surgical outcome for the 11 subjects seen postoperatively show improvement in the gait of 10 subjects. When combined procedures were done, improvement could often be correlated with one of these procedures. This is most evident in those subjects who had combined split tibialis anterior and tendo-achilles lengthening procedures. Sagittal plane movement patterns always improved but the degree of varus was only minimally improved upon.

Discussion

A detailed analysis is still to be done following completion of each child's postoperative assessment. From this we will attempt to define causes for surgical success or failure. These results will be presented.

A substantial number of people with cerebral palsy undergo some form of surgery to correct or prevent joint-bone deformities. This study is the first concerted effort to examine, in depth, the results of surgery of muscles acting about the ankle joint. Results from this study should provide new information regarding the outcome of particular surgical procedures and aid in the development of more appropriate surgical answers.

Acknowledgement

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UTILISATION DU TAPIS MOTORISÉ DANS LA MARCHE:
ÉTUDE ÉLECTROMYOGRAPHIQUE DE VALIDATION

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RÉSUMÉ - Huit sujets ont participé à une étude ayant pour but de comparer la marche effectuée sur trottoir et sur tapis motorisé. Il est démontré que pour les muscles Sol, RF, VM et TA, les enveloppes linéaires (EMG) sont identiques dans ces deux conditions. Cependant, le BF semble être affecté par l'action du tapis motorisé.

ABSTRACT - Eight subjects participated in an EMG study aimed at comparing walkway and treadmill gaits. All muscles investigated showed similar linear envelopes (Sol, RF, VM and TA) except for one (BF) which seemed disturbed while performing on the treadmill.

L'utilisation du tapis motorisé a grandement été exploitée dans les domaines de la physiologie de l'exercice et de l'ergonomie (Burke, 1979 ; Sanchez et al., 1979 ; Soule et al., 1978). De toute évidence, cet appareil en est un des plus utiles pour l'étude de différents paramètres physiologiques (Dal Monté et al., 1973) puisque lors de la course ou de la marche, différentes angulations et/ou vitesses peuvent être sélectionnées.

Face à l'étude de la marche comme telle, le tapis motorisé a été utilisé chez l'humain lors d'études électromyographiques (EMG) portant sur les effets de la mise en charge (Medeiros, 1978), sur la vitesse de la démarche (Brandell, 1976, 1977 ; Cavanagh & Gregor, 1975 ; van der Straaten et al., 1975), ainsi que sur la fidélité du signal EMG (Elliott & Banksby, 1976) avec application des résultats à la démarche réalisée sur trottoir.

Cette réplique en laboratoire d'une condition connue, c'est-à-dire la marche sur trottoir, permet de maximiser sur les éléments de validité interne (contrôle de variables) de toute expérimentation faite sur la marche. Cependant, en ce qui concerne les aspects de validité externe, c'est-à-dire l'équivalence de la marche sur trottoir comparativement à la marche sur tapis motorisé, le débat demeure encore sans réponse claire (Brandell & Williams, 1974 ; Elliott & Blanksby, 1976 ; Nelson et al., 1972 ; Pugh, 1970 ; Woolley & Winter, 1979).

Conséquemment, autant le tapis motorisé a été utilisé principalement en recherche sur des sujets impliquant la marche, autant un certain intérêt a été porté sur l'aspect de validité externe de cet instrument. Jusqu'à présent cependant, il ne semble pas exister d'étude exhaustive comparant des données EMG obtenues lors de la marche, chez l'humain, pratiquée autant sur tapis motorisé que sur trottoir. La présente étude a donc pour but de présenter de telles données afin de valider l'utilisation de cet instrument, a) lors de l'étude du contrôle musculaire dans la marche et, b) pour son utilisation dans la rééducation à la marche impliquée dans certains programmes de réadaptation.

METHODOLOGIE

Un total de huit sujets (N = 8) appartenant aux deux sexes participèrent à l'expérience en tant que volontaires. Leur moyenne d'âge était de 24,5 ans (s = 4,3). Aucun d'eux ne possédait une histoire de lésion du système neuro-musculaire. Ceux-ci furent divisés en fonction de leur dominance (D/G). Le membre inférieur dominant fut celui sur lequel la collecte de données fut effectuée.

La marche fut effectuée sur un trottoir avec une cadence stable, c'est-à-dire maintenue à l'aide d'un métronome. Cette cadence fut sélectionnée par chacun des sujets et identifiée par eux comme étant confortable et normale ($\bar{X}$ = 106,1 et s = 3,3 pas/min.). Le sujet eut par la suite à marcher sur un tapis motorisé de type Collins Compact. La même cadence que celle utilisée sur le trottoir fut conservée, toujours à l'aide d'un métronome. La vitesse de déroulement du tapis motorisé fut sélectionnée par le sujet et par la suite maintenue constante afin de la rendre compatible avec la cadence antérieurement sélectionnée sur le trottoir.

Cinq muscles du membre inférieur dominant furent choisis pour fins d'investigation électromyographique : soleus, rectus femoris, biceps femoris, vastus medialis et tibialis anterior. La sélection de ces muscles fut faite en fonction de leur relation agoniste/antagoniste et/ou de leur relation de synergistes monoarticulaires/biarticulaires.

Des électrodes de surface (Beckman) furent utilisées dans le but de capter le signal EMG par technique bipolaire. Ces électrodes furent placées sur le ventre du muscle investigué suivant le sens longitudinal des fibres musculaires. Une technique conventionnelle de préparation de la peau et d'application des électrodes fut suivie. Parallèlement aux cinq canaux d'EMG utilisés, des signaux provenant d'interrupteurs placés sous les deux talons des souliers et indiquant le contact des talons avec le sol furent transmis par télémétrie (FM, modèle 370 Biolink telemetry system, Biocom Inc., Culver City, Cal.). Les fréquences transmises des signaux EMG se situaient entre 15 et 180 Hz.

Les profils musculaires utilisés dans la présente étude ont été obtenus en transformant les signaux EMG en enveloppes linéaires. Pour ce faire, le signal fut rectifié, puis filtré à l'aide d'un filtre passe-bas de 6 Hz. Ces enveloppes furent par la suite transformées en données numériques à l'aide d'un ordinateur NOVA II, utilisant une fréquence d'échantillonnage de 50 Hz. L'amplitude du signal fut normalisée en utilisant les données (amplitude en mV sous une enveloppe linéaire) d'une contraction maximale volontaire (Winter, 1976). Cette contraction était de nature isométrique , le tout impliquant trois secondes de maintien de temps de contraction pris en une position mitoyenne de l'articulation concernée. Chacun des cycles de marche, pour chacun des sujets, eut son temps normalisé en valeurs de pourcentage (%).

Dix cycles de marche furent analysés pour chacun des huit volontaires. Les valeurs numériques telles qu'échantillonnées sur les enveloppes linéaires permirent d'obtenir des valeurs d'amplitude moyenne pour chacune de celles-ci, ainsi que d'établir les niveaux de corrélation (r de Pearson) de paires d'enveloppes pour fins de comparaison.

RESULTATS ET DISCUSSION

Le tableau I présente une vue d'ensemble des résultats obtenus pour chacun des muscles investigués. Il peut être tiré de cette présentation des données inter-sujets que peu sinon pas de différence existe entre les deux conditions expérimentales investiguées, c'est-à-dire marche sur trottoir comparativement à la marche sur tapis motorisé.

Tableau I : Résumé de l'analyse statistique comparant les profils électromyographiques provenant de la marche sur trottoir et de la marche sur tapis motorisé.

Muscle		
Sol	r = 0.993 R^2 = 0.986 Pte = 0.940	$\bar{X}$ = 21.700 $\bar{Y}$ = 21.500
RF	r = 0.982 R^2 = 0.965 Pte = 0.935	$\bar{X}$ = 3.322 $\bar{Y}$ = 3.376
BF	r = 0.972 R^2 = 0.944 Pte = 1.123	$\bar{X}$ = 9.048 $\bar{Y}$ = 8.436
VM	r = 0.997 R^2 = 0.994 Pte = 0.929	$\bar{X}$ = 4.914 $\bar{Y}$ = 5.276
TA	r = 0.993 R^2 = 0.986 Pte = 0.979	$\bar{X}$ = 14.910 $\bar{Y}$ = 15.332

Le coefficient de corrélation (r) de Pearson fut obtenu en contrastant les valeurs numériques des enveloppes linéaires moyennes, pour chaque muscle, provenant de la marche sur trottoir et de la marche sur tapis motorisé. "R^2" représente le coefficient de détermination et "Pte" la pente de la ligne de régression. $\bar{X}$ représente la valeur d'amplitude moyenne sous l'enveloppe linéaire moyenne de la marche sur trottoir et $\bar{Y}$ celle de la marche sur tapis motorisé, exprimée en % d'une contraction isométrique maximale volontaire.

Sol = Soleus ; RF = Rectus Femoris ; BF = Biceps Femoris ; VM = Vastus Medialis ; TA = Tibialis Anterior.

Les valeurs du r de Pearson représentent le degré de similitude hautement élevé des profils musculaires contrastés. Le coefficient de détermination (R^2) représente l'importance, en termes de variance expliquée par la régression linéaire, de la relation trouvée entre les deux profils musculaires comparés. Pour sa part, la valeur de la pente (Pte) caractérisant la ligne de régression de chacun des contrastes effectués devient un indice de la similitude des valeurs d'amplitude obtenues sous chacun des profils comparés. Comme toutes ces pentes oscillent à des valeurs pratiquement égales à 1.0, il peut être avancé que non seulement les profils électromyographiques de ces deux conditions sont semblables (suivant les valeurs de r) mais qu'en plus les valeurs d'amplitude du signal EMG normalisé sous ces profils sont pratiquement les mêmes. De fait, les valeurs moyennes d'amplitude exprimées (Tableau I) représentent bien cet état de choses.

Une particularité est cependant à noter. Le profil d'activation du muscle biceps femoris semble affecté lors de la marche sur le tapis motorisé comparativement à la marche sur trottoir. Ce fait s'observe dans les données individuelles provenant de chacun des sujets investigués par une plus grande variation du signal EMG lors de la phase d'appui ou de mise en charge du cycle de marche.

La présente étude vient donc, en partie, valider l'utilisation du tapis motorisé lors de l'étude de la marche chez l'humain. Ceci vaut du moins pour les résultats EMG et semble valoir également pour des données de type temporel (Nelson et al., 1972). De tels résultats impliquent même que cet appareil saurait être avantageux dans la rééducation à la marche de certaines populations participant à un programme global de réadaptation. Finalement, ce même appareil serait en mesure de faciliter la tâche à tout investigateur clinique désireux d'évaluer la condition neuro-musculaire du système locomoteur (voir Knutsson & Richards, 1979) et son progrès suite à un programme de thérapie reçu.

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PATTERN RECOGNITION USING ANGLE-ANGLE DIAGRAMS FOR GAIT ASSESSMENT

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ABSTRACT - An Euclidean distance measure is proposed for measuring deviation from normal on the gait angle-angle diagram. The measures will have significance in tracking rehabilitation progress and in evaluating the efficacy of procedures impacting gait disabilities.

RÉSUMÉ - Une mesure de la distance euclidienne est proposée pour mesurer l'écart par rapport à la normale sur un diagramme des angles (genou/hanche) de la démarche. Cette mesure aura de l'importance pour l'étude du progrès de la réhabilitation et de l'évaluation de l'efficacité des méthodes ayant pour objet les handicaps de la démarche.

Introduction

The assessment of human locomotion is, at present, very often carried out through visual observation by a trained clinician. In a sense, we are calling on the inherent pattern recognition abilities of the human brain specifically trained through many years of clinical experience. The development of new tools to augment this skill would indeed be valuable to the clinician.

Time histories of hip angles versus knee angles in the sagittal plane have often been used to represent the variation of the lower limb joints during one complete gait cycle. By integrating multiple joint trajectories on one graph, coordination effects can be presented. Thus, the angle-angle diagram serves as a potential tool for investigating pathologial conditions in walking. A systematic method for interpretation of these diagrams would be a useful tool for patient assessment. The result of such a structured analysis would provide a measure of consistency to the interpretation of these diagrams and may, furthermore, identify underlying physiological bases for the gait disability.

A typical angle-angle plot is shown in Figure 1. If one traverses the loop in the clockwise direction, a time history of the knee and hip angles is defined for one complete gait cycle. Interpretations of the biomechanics occurring throughout the loop may be found in many references (1,2,3). This paper is concerned with pattern recognition techniques, however, and will not attempt to provide complete information on diagram interpretation.

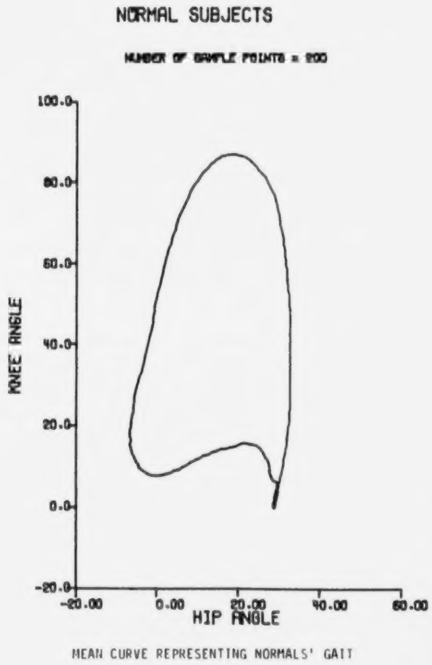

Figure 1

Previous Works

Two papers (1,2) authored by C. Hershler and M. Milner motivated the development of this project. The authors discuss techniques developed at the Chedoke Rehabilitation Center for extracting pertinent information from angle-angle diagrams to aid in locomotion analysis. Several key parameters were suggested in the papers; however, only three (perimeter, area, and P = perimeter/$\sqrt{area}$) were pursued. In particular, the ratio P was not only indicative of diagram shape, but was, more importantly, invariant with respect to walking speed. Since a change in either joint angle increases the perimeter of the loop, it has been suggested that the perimeter measure would be indicative of coordination between the two joints. Unusual combined rotations in the hip and knee joint will surface as an increase in the area measurement. This dimensionless parameter, P, is used as an important measure in vision based inspection systems to identify objects. This measure alone cannot define actual shape, but may be used to indicate overall differences in shape. Since it is suggested that control and coordination may be indicated by these parameters (1,2), the variation of these parameters with respect to a particular gait pathology may provide clinicians with important information.

Discussion

The parameters pursued by Hershler and Milner prove to be useful in angle-angle loop shape recognition. However, several important drawbacks to their approach must be recognized. The perimeter and area are correlated measures and give no information about the location of the curve in the hip, knee angle space. Consequently, additional information about the location of the centroid of the loop would be required. However, even then, the shape of the curve is not completely specified. For example, curves with entirely different shapes exist with the same perimeter, area, and centroid. Therefore, these three parameters are not sufficient for determining how the curve relates to a "normal" angle-angle loop, thus motivating the investigation of a measure of deviation from normal.

Feature Definition

The features developed in this paper for angle-angle diagram analysis are based on a "deviation from normal" measure. Given a sampling of normal curves, a mean curve is determined. A boundary around the mean curve is defined based on the maximum deviation any of the normal curves make from the mean. This boundary defines the maximum distance from the mean, typical of normals. If the patient's gait under consideration deviates outside the boundary area at any point in time, it is considered an abnormal angle-angle point, and the Euclidean distance between the point and the boundary is computed as a function of time. Furthermore, as one traverses the loop, each deviation is added to a running sum to give a final total deviation from normal measure. This measure, in conjunction with the history of the deviation measures, may be valuable for assessing the severity of pathological conditions.

Several factors must be noted. A sampling of normal curves is used in the generic sense to mean a sampling of curves that is "normal" for the subject being tested. Age, sex, weight, and walking speed have an effect. Therefore, the mean curve must be determined from carefully selected data from subjects which match the subject being tested. Since the final total sum measure is an additive measure through the cycle, it gives no temporal or spatial information. This total deviation measure suffers the same drawback as the parameters discussed previously. Therefore, it is desirabale to also consider the time history of the actual deviation from the mean curve (see Figure 2.) In this manner, the summation gives a quantitative measure from normal, while the time history of deviation indicates the source of the deviation as well as identifies the particular phase of the cycle where significant contributions to the deviation measure has occurred.

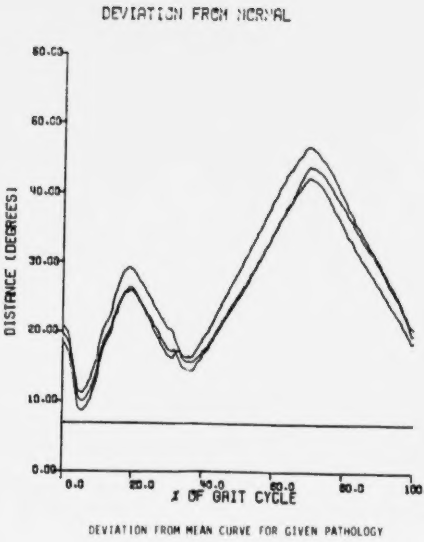

Figure 2

Conclusions

Assuming a statistically significant data base, the results would provide the clinician with a "severity measure" of the pathology. The higher the "deviation from normal" measure, the further away from normal gait the patient will be. Furthermore, the deviation from normal trajectory indicates the phase of the cycle where the abnormality occurred. The individual hip and knee angle trajectories and their deviation from normal would provide further information about the abnormal joint and the time of occurrence.

Rehabilitation progress may be followed by tracking the deviation measure as an indication of whether the patient's gait is moving closer to "normal." Furthermore, the efficacy of various surgical and other rehabilitative procedures may thus be quantitatively assessed.

Acknowledgements

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SWING THROUGH GAIT ON AXILLARY CRUTCHES - A FORCE ANALYSIS APPROACH

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ABSTRACT - A force study on foot and axillary crutches during the swing through gait was carried out. Results can help to monitor the proper use of axillary crutches and caution their prescription to patients with unsound lower and upper extremities.

RÉSUMÉ - Une étude des forces agissant sur le pied et les béquilles au cours du balancement pour la marche a été réalisée. Les résultats peuvent faciliter le contrôle de la bonne utilisation des béquilles et inspirer la prudence dans le cas d'une prescription à des patients ayant des membres inférieurs et supérieurs fragiles.

INTRODUCTION

The use of axillary crutches are not without problems. Complications such as axillary artery thrombosis [1], and radial nerve compression [2], had been reported. One major factor that could be the cause of these complications is the misuse of this type of crutches. It has been reported [2] that sensation is rarely affected by the compression of the radial nerve by the axillary bar in such instances and for this reason, motor weakness may become subtly worse. Jebsen (1967) [3] warned that this may lead to complete paralysis of the triceps and forearm extensor muscles.

The purpose of this paper is to present a biomechanical study on the axillary crutches during swing through gait: (i) to compare the ground-foot reaction during crutch gait and normal walking; (ii) to characterise the weight-bearing nature of the axillary crutches through correct and incorrect usage and (iii) to discuss the possibility of designing a biofeedback system to monitor the correct use of axillary crutches.

INSTRUMENTATION & METHODOLOGY

A Kistler force plate was used to monitor the ground reactions on the right foot and the right crutch. Forces were also monitored at three different locations on the right crutch. To do this, strain gauges were installed in a full-bridge configuration near the crutch tip, the front and back of the upper part of the crutch. The gauges only measured the axial strains hence the force exerted on the crutch. The instrumented crutch was calibrated using a simple lever system. In conjunction with the force study, the crutch gait stride characteristics were also determined. A simple setup was designed for this purpose. It comprised basically (i) a 0.76 metres by 3.66 metres conductive walkway (ii) three metal contacts fixed onto the head, midsole and toe positions of the sole of the shoes (iii) a metal contact at the crutch tip, (iv) a pen chart recorder and (v) a 6-V battery pack as the input source. The circuit in this setup was completed each time the sole and/or the crutch tip made contact with the conductive walkway.

Seven normal male subjects were used in the study. Prior to the commencement of the gait trials, the subjects were instructed to walk around the laboratory at their comfortable walking speeds using the instrumented crutches. The gait trials consisted of the subjects (i) walking normally (ii) walking using the crutches (a) correctly, that is with the axillary bar about three fingers below the anterior axillary fold [3] and (b) incorrectly, that is bearing their weight on the axillary bar.

RESULTS AND DISCUSSIONS

The results from the gait study showed that (i) the normal gait comprised 60% stance phase and 40% swing phase over one cycle for cadance of 104 to 122 steps per minute (the average speed of 1.22 m/s); (ii) the crutch gait comprised 70% stance phase and 30% swing phase, the average speed of crutch walking was about 0.8 m/s; (iii) the right crutch stance was about 53% of the cycle.

Subject	Crutch Gait		Normal Gait
	Crutch	Foot	Foot
A	0.54	1.33	1.04
B	0.51	1.28	1.15
C	0.51	1.13	1.11
D	0.52	1.36	1.29
E	0.50	1.38	1.16
F	0.49	1.13	1.12
G	0.50	1.45	1.02
Average	0.51	1.29	1.13

Table 1. Ground Reaction Forces (correct usage).

In the force analysis, only the vertical force on the foot was considered and the force in the axial direction of the crutch was analysed. The results from the force study are summarised in Table 1. All results of the ground reaction are non-dimensionalised as a ratio of the body weight. The table gives the maximum ground reaction on the right foot and the right crutch. The above results show an increase in the ground reaction force on the lower limb of about 14% compared to normal walking which confirms the findings of Sankarankutty and Stallard [4] though the latter reported an increase of about 20%. Thus caution is needed in prescribing such crutches for patients with unsound lower extremities. Fig. 1 shows an example of typical forces in the crutches during crutch walking when they are (i) correctly and (ii) incorrectly used.

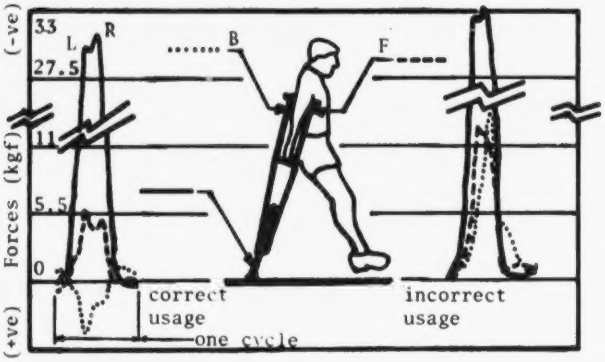

Fig. 1 Crutch Forces during walking.

One cycle shown in Fig. 1 is defined to be from one crutch strike to another. The crutch tip curve shows two peaks (L and R) which correspond to the force at crutch strike and crutch off respectively. The above figure also shows that when the crutches are correctly used, the axial force in the front of the upper part of the crutch (indicated by F) is always compressive and greater in magnitude than that of the back (indicated by B) which is usually tensile. This suggests that there is a considerable amount of bending on the axillary bar of the crutches. On the other hand, for incorrect usage, the force at position B is consistently higher than that at F and both are in compression. There is hardly any bending on the axillary bar. The loading system on the crutches can be idealised into one of axial load acting at the centre of the axillary bar plus a pure bending moment. This idealisation provides a very useful information on the magnitude of forces acting on the upper extremities of a crutch user. Table 2 summarises the forces on the crutch tip, the axillary bar and hence the hand grip, the latter is obtained from the difference between the crutch tip and the axillary bar.

It can be seen that for correct crutch usage, the force on the axillary bar is very small (averaging 0.05 of body weight) whereas for incorrect usage, the force is quite high (averaging 0.34 of body weight). This could have adverse effects on the axillary fold. Thus, these results can be used to monitor the correct usage of the crutches by comparing the forces on the axillary bar to that of the crutch tip. A design for such a gadget for this purpose is already underway.

Subject	Crutch Tip	Axillary bar	Hand Grip
A	0.54 (0.55)	0.09 (0.27)	0.45 (0.28)
B	0.51 (0.54)	0.02 (0.35)	0.48 (0.19)
C	0.51 (0.52)	0.03 (0.26)	0.48 (0.27)
D	0.52 (0.55)	0.03 (0.39)	0.49 (0.16)
E	0.50 (0.52)	0.04 (0.34)	0.46 (0.18)
F	0.49 (0.51)	0.07 (0.37)	0.42 (0.14)
G	0.50 (0.53)	0.05 (0.40)	0.45 (0.13)
Average	0.51 (0.53)	0.05 (0.34)	0.46 (0.19)

Table 2 Ground Reaction as Ratio of Body Weight.
NB: Values in brackets are for incorrect usage.

The force on the hand grip is the force transmitted on to the arms of the crutch user. It can be seen that for correct crutch usage, this force is very high (averaging 0.46 of the bodyweight). This is a contraindication on patients who have weak or diseased upper extremities. For incorrect usage, as expected, the force transmitted to the arms is quite low (averaging 0.19 of the body weight) since the weight is borne on the axillary bar.

CONCLUSIONS

For correct crutch usage, (i) there is an increase in the vertical ground reaction force on the lower limb of about 14% compared to normal walking; (ii) the force transmitted to the arms is about 0.46 of the body weight. These facts should be borne in mind in prescribing the axillary crutches to patients with unsound lower and upper extremities. By comparing the forces on the axillary bar and the crutch tip, one can monitor the proper use of axillary crutches.

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SELF CONTAINED SYSTEM FOR REAL-TIME MEASURING THE CENTER OF GRAVITY MOVEMENT DURING WALKING

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A new technique for the measurement of the displacement of the center of gravity of human body during walking is discussed. This measuring system basically consists of three kinds of sensors on passive orthosis and a microcomputer, and can measure the center of gravity movement in real-time and independently of environmental conditions.

Une nouvelle technique pour la mesure du déplacement du centre de gravité d'un corps humain pendant la marche est étudiée. Ce système de mesure consiste en trois sortes de capteurs montés sur une orthèse passive et d'un microordinateur. Il peut mesurer le mouvement du centre de gravité en temps réel et indépendamment des conditions d'environement.

An exoskeltal active orthosis for lower extremities is under development at the Institute of Biomedical Engineering. This orthosis, which should be used by patients who have paralyzed lower limbs, aims to walk with supporting the patient's body. At this active orthosis walking, it is a great advantage to know the spatial position of the center of gravity of walk system in order to keep its balance. Until now, two techniques have been studied for measuring the displacement of the center of gravity. One is the method using force plate, which can measure not its spatial position but its projected point on the horizontal plane. The other is a stereometric method, in which stereophotogrammetric technique or stereosonic system is involved.

For active orthosis control, a system for measuring the center of gravity movement must satisfy the restriction that movement data must be obtained both in real-time and independently of environmental conditions; active orthosis may walk on not only level ground but also stairs, slops and any other place where standard points in inertial reference frame are hard to be commonly referred. However, both of the two techniques mentioned above have potential and fatal drawback on this latter restriction: they need some adequate standard points in inertial frame. Therefore, another new method must be developed for this sake. A new method for measuring the center of gravity movement of walk system is described below.

The block diagram of this measuring system is shown in Figure 1. It can be classified into sensor part and data processing part. Sensor part contains three kinds of sensors used to detect absolute angular displacement of one segment, reletive joint angular displacement and foot-floor contact sequences during walking. For obtaining the absolute angular motion data, an inclinometer utilizing accelerometer is difficult to be used, since it causes a certain error under the influence of inertial forces. A piezo-electric vibrating angular rate sensor, a kind of inertial sensor, is used, and the output of this sensor may be integrated to obtain the absolute angular data with respect to inertial frame. The voltage-to-frequency converter and up-down counter shown in Figure 2 function as an integrator for this sake. Two pairs of angular rate sensors and integrators are put on upper torso for measuring its sagittal and frontal plane's absolute angular motions. Relative rotations of hip, knee and ankle joints of left and right legs are measured by six potentiometers located on their respective places of passive orthosis for gait pattern measurement. Though hip and ankle joints could not be classified strictly as planer joints, to make matters simple, this passive orthosis has joints of one degree of freedom, which allow rotation only in sagittal plane. And a pair of foot switch sensors made of pressure-sensitive conductive rubber obtain the foot-floor contact sequences data. Data derived from these three kinds of sensors are given to DEC microcomputer PDP11/23 through analog-to-digital converter or digital I/O unit.

The center of gravity movement is calculated from these raw data as follows. In the first, the center of gravity location in human

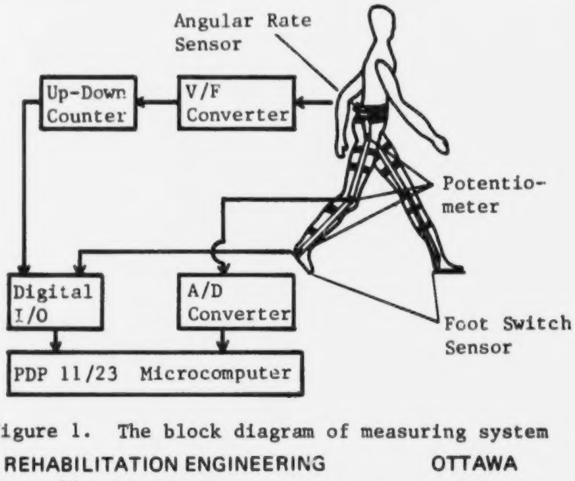

Figure 1. The block diagram of measuring system

body is assumed to be always at the point anatomically investigated, whatever posture the subject would be in, during walking. Then the center of gravity displacement can be evaluated from the geometry of the leg in stance phase, based on the models shown in Figure 2, and its values are given as follows.

$$X_g = L_b \sin\theta_{bs} + L_t \sin\theta_t + L_l \sin\theta_l + A \quad (1)$$

$$Y_g = L_h \cos\theta_{bf} + L_b \cos\theta_{bs} \sin\theta_{bf} \quad (2)$$

$$Z_g = L_b \cos\theta_{bs} + L_t \cos\theta_t + L_l \cos\theta_l + B \quad (3)$$

$$\theta_{gs} = \tan^{-1}(X_g / Z_g) \quad (4)$$

$$\theta_{gf} = \tan^{-1}(Y_g / Z_g) \quad (5)$$

where

$$A = \begin{cases} L_{fh} \sin\theta_f & \text{(at heel contact)} \\ L_{ff} \sin\theta_{ff} & \text{(at heel off)} \end{cases}$$

$$B = \begin{cases} L_{fh} \cos\theta_f & \text{(at heel contact)} \\ L_{ff} \cos\theta_{ff} & \text{(at heel off)} \end{cases}$$

Absolute angle of each segment θ_t, θ_l, θ_f and θ_{ff} can be calculated by some addition and subtraction of absolute angle of upper torso and relative joint angles. As discussed previously these calculations of Xg, Yg, Zg and center of gravity angle θ_{gs} and θ_{gf} must be done in real-time. But these equations contain many multiplications and trigonometric functions, which take much calculation time on microcomputer. To shorten calculation time, the products such as $L_b \cdot \sin\theta_{bs}$, $L_t \cdot \sin\theta_t$ and so on have been calculated beforehand and stored in table. And then by referring this table, Xg, Yg, Zg, θ_{gs} and θ_{gf} can be calculated in less time. The calculation time becomes about 1 millisecond that is 1/30 of the case where calculations are done as expressed by the equations. The center of gravity angle evaluated by this technique is given in Figure 3 with foot-floor contact sequences. This data was measured in a normal subject at the beginning of walking. Though only θ_{gs} and θ_{gf} data are shown in Figure 3, other data such as Xg, Yg and Zg were also evaluated simultanenously.

This measuring technique will be utilized by not only active orthosis control, but also rehabilitation of patients who lose statokinetic functions or gait pattern measurement in optical circumstances where measurement is hard to be done.

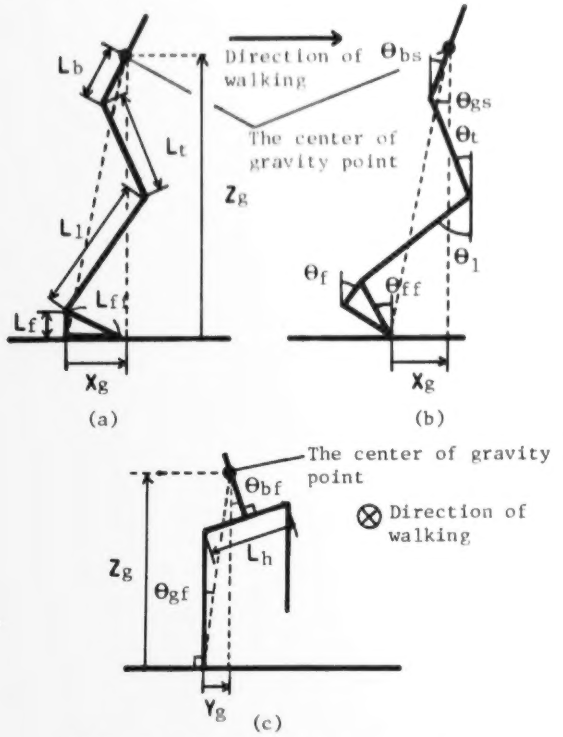

Figure 2. The models for evaluating the center of gravity movement

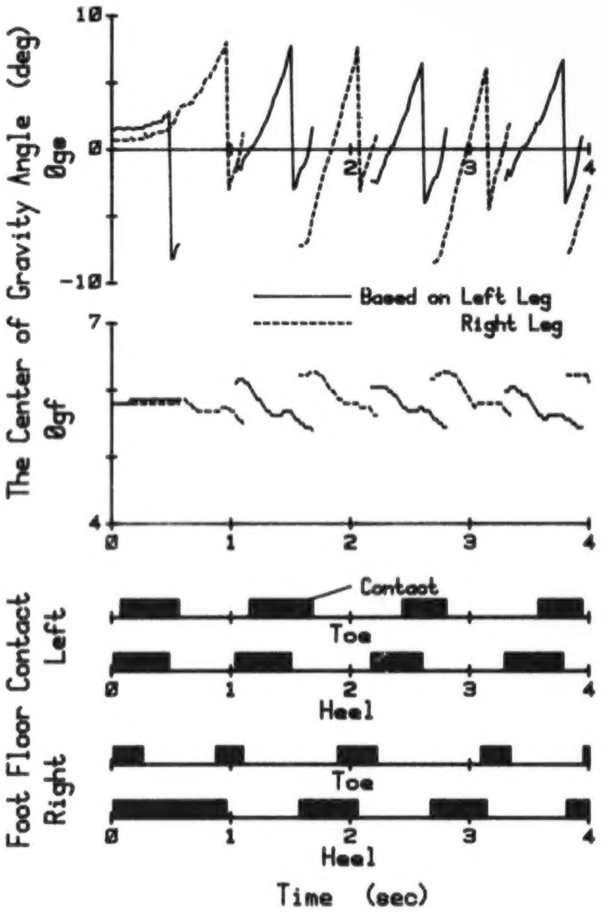

Figure 3. The center of gravity movement at the beginning of normal subject's walking

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A FRAMEWORK FOR FORMALIZATION AND CODIFICATION OF PATIENT LOCOMOTOR DATA ON A MICROCOMPUTER

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The standardisation of biomechanical data presentation using symbolic movement notation system, can help in data interpretation, clinical decision making, information exchange between clinics and training of personnel. A microcomputer based prototype of this formalization is presented.

La standardisation des données issues de mesures biomécaniques utilisant un code symbolique pour les différentes étapes du mouvement, s'avère utile dans l'établissement des diagnostics. Un modèle sur micro-ordinateur utilisant ce système est présenté.

The variability and inaccuracy of medical data have been well documented by many researchers (1). The effect this has on medical decision making is obvious. In rehabilitation clinics, when dealing with patients with ambulatory problems, the situation is further confounded. An integral part of the patient's treatment involves biomechanical analysis of their movements, specifically their locomotor capability. This type of analysis yields objective data that are quantifiable and hence should aid in clinical decision making. Unfortunately, the mode of data collection as well as the data collected vary from clinic to clinic. It ranges from visual observation by a team of specialists, to analysis of biomechanical measures of usually level surface walking (2). The debate over the relative merits and demerits of each system and the associated measures continues. Even when there is a clear consensus on the mode and type of data to be collected such as the electrocardiogram, studies have shown inter-observer variability in interpreting these results (1). Therefore it is easy to understand the difficulties in interpreting the various forms of biomechanical data obtained in rehabilitation clinics. The different data formats make it impossible to exchange data between clinics. The training of personnel becomes very clinic specific. The large number of patients attending rehabilitation clinics to improve their ambulatory capacity makes the solution of this problem particularly important.

If the data presentation can be formalized and include all the measures that are collected, one can channel efforts into better interpretation of the biomechanical data and improve the clinical decision making. It has been suggested that symbolic notation to describe movement (2) can help in this formalization of data presentation. The focus of this paper is the formalization and codification of biomechanical data using symbolic notation on a microcomputer. A prototype of the proposed system is described.

FORMALIZATION OF DATA PRESENTATION

The use of symbolic notation allows for easily readable, economical storage of biomechanical data (2). The data will be presented in the form of a chart. Three charts, corresponding to the three hierarchical levels of biomechanical data, will be implemented. These are:

a) Kinematic Data Chart: This will allow notation of temporal variables such as stance/swing phase duration, walking speed, angular displacement of the lower limb joints, data on upper body displacement and on any external support used. The chart format presents data for standing and one cycle of walking data on any surface.

b) Kinetic Data Chart: The moments generated at the joints can be notated on a chart similar to the one described before. Estimates of peak moment values will be obtained from the kinematic data if the inverse dynamic analysis of kinetic data is not available.

c) Muscle Data Chart: Data on muscle activity using either quantified EMG or muscle strength values (muscle charting) can be notated on a chart similar to the kinematic chart.

These hierarchical charts can provide 'biomechanical' diagnoses by aiding in defining a clear biomechanical logic for interpreting the data.

CODIFICATION OF DATA ON MICROCOMPUTER

With advances in microcomputer technology and concurrent reduction in costs make it attractive for use in medicine (3). Microcomputer-based implementation of the biomechanical data charts offers the following advantages:

1. Eliminate errors in data collection, since it prompts for relevant data at appropriate times and is able to integrate data from diverse sources. For example, data on external support used for ambulation and visual observation of upper limb data can be included along with any lower limb data.
2. Because of its ability to retrieve records (patients' previous records or the records of

similar patients) for comparison and statistical analysis, it can provide 'data base knowledge' and an empirical basis for clinical decision making.

3. The computer based charts can improve the accuracy and reliability of clinical decision making, enhance our understanding of the structure of biomechanical knowledge and of clinical decision making.

DESCRIPTION OF A PROTOTYPE

The prototype is being developed on an IBM Personal Computer system with 64K memory, dual floppy disk drives, a dot matrix printer and a colour monitor which provides higher resolution graphics than the monochrome monitor. This computer was chosen because of its graphic capabilities and the availability of appropriate software and hardware accessories. The programs are written in BASIC language because it has easy screen commands, it comes with the PC and is available for all major microcomputers. This would make the system machine portable.

a) Symbol Library: The kinematic symbol set, each symbol created on a 16 x 25 pixel grid, is shown in Fig. 1. The program is capable of creating symbol sets for the kinetic and muscle data chart.

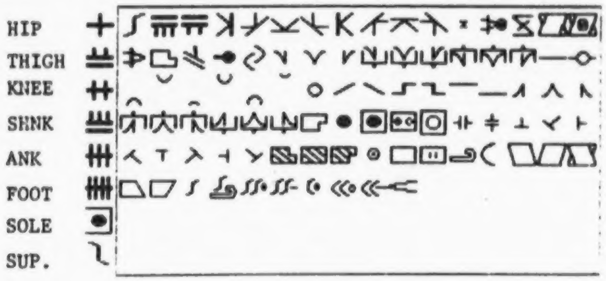

FIGURE 1: Computer generated, kinematic symbol chart Each row records data for different body segments.

b) Disk Utilization: One disk drive is treated as a system disk drive and contains the Program files, Symbol library, Help file and Patient file directory. The second unit will be the current disk drive for recording and updating patient's data. The patient data are stored as sequential files with a diskette allocated to each patient. Each chart is stored as four matrices, one each for the X and Y co-ordinates of the symbol, one for the type of symbol and one for any numeric data to be included. The three character extension in the file naming convention will be used to keep track of patients' visits. The patient identifier in the patient file directory can be user specified.

c) Chart Generation: The system will have three modes of input which the user can select to generate a chart. They are:

1. Direct interaction with the screen using keyboard commands. A sample kinematic chart for a normal level walking generated using this mode of input is shown in Fig. 2.

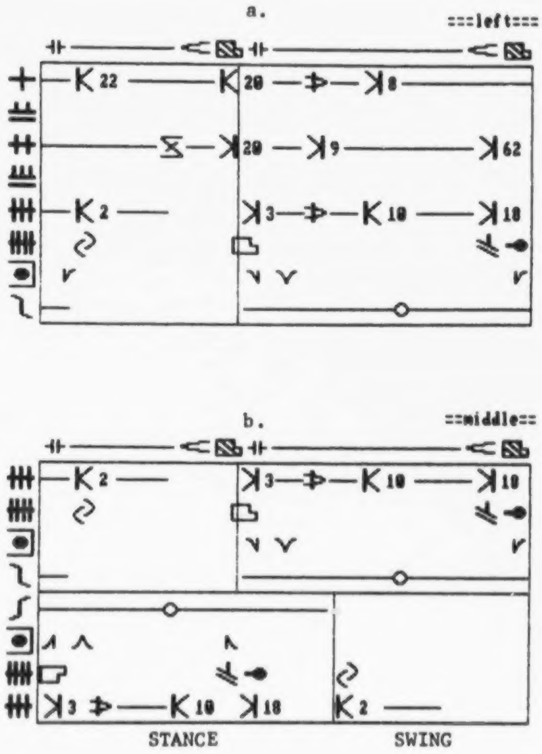

FIGURE 2: Normal kinematic data chart for level walking. a) For left side, b) shows four rows for both right and left side.

2. Through an interactive program which prompts the user to measure and/or answer specific questions (such as what is the stance/swing phase duration ratio?). These answers are interpreted to produce a chart. The questions in this interactive program have been written.
3. Through an A/D interface with an existing data collection system in a clinic, the measured data can be used to generate at least part of the chart. Additional information can be fed in via either of the above two methods.

It is hoped that this system can be a catalyst in providing better health care through more organized and repeatable procedures.

ACKNOWLEDGEMENTS

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POLIO GAIT IS ANTALGIC GAIT

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ABSTRACT - A methodology is described for quantification of the distribution of forces acting on the foot of a polio victim. Its use is illustrated by the analysis of results on the subject's deformed foot. These results can further be used to prescribe suitable lower limb bracing and corrective footwear.

RÉSUMÉ - On décrit une méthode pour quantifier la distribution des forces agissant sur le pied d'une victime de la poliomyélite. Son utilisation est illustrée par l'analyse des résultats obtenus concernant le pied déformé d'un sujet. Ces résultats peuvent également servir pour prescrire des appareils et des chaussures orthopédiques appropriés.

INTRODUCTION:

The structure and function of the foot is critical to an understanding of the mechanics of gait. The foot affects the relating of the components of the lower extremity, and thus the resulting gait pattern.

The distribution of forces between the foot and the ground surface can also reveal information about the structure and function of the foot itself, and the resulting characteristics of the whole body. This information can be useful for a number of purposes:

1. anatomical inspection of the foot itself.
2. neuromuscular examination of the trunk and lower limb skeleto-motor system as reflected in characteristic loading patterns at the interface of the foot and surface.
3. for prosthetic and orthotic designers, orthopaedic surgeons, researchers in biomechanics, and rehabilitation engineers.

During the past century, numerous methods have been proposed for measuring the distribution of forces acting on the foot. However, none of these have resulted in a composite curve of vertical ground reaction forces under different regions of the foot. The technique developed by Ranu et al (1980) is capable of doing this. In this paper the foot to ground reaction forces of a female polio victim are reported.

MATERIALS AND METHODS:

Description of load cell:

A miniature triaxial load cell 14 mm thick x 19 x 19 mm in overall size has been developed (Figure 1). It consists of 4 loops of load bearing elements placed symmetrically around a 12.5 mm square which is located at the center of the load cell. There is no contact between the top and bottom square plates to allow load transfer through these loops. A total of 16 small foil-type strain gauges are used to achieve triaxial force output with minimal cross-talk.

Prior to installation in the shoe, each load cell was calibrated statically along each of its 3 sensitive axes. An orthogonal coordinate system was used in order to identify the direction of the applied force. During loading all three channels were monitored in order to check for cross-talk.

Experimental procedure:

A female subject who had developed polio at the age of four years which effected her right lower leg and right foot (lesion at the level of L_5-S_2 segment of the spinal cord) was twenty three years old at the time of this investigation. Her right shoe was instrumented with 5 miniature triaxial load cells. They were mounted individually in the shoe, two in the heel, one under the toe and two under the 1st and 5th metatarsals as shown in Figure 2. The height of the shoe was not changed. The subject was asked to become accustomed to the instrumented shoe before she walked.

Data acquisition:

The 15 channels of force data were recorded on an analogue tape recorder via lightweight flat trailing cables which were suspended on a series of rollers in a low-friction track. A mini-computer was used to provide on the spot data digitization and processing of the 15 channels. The data could be displayed on a screen or copied into a hard copy for a permanent record.

RESULTS:

From the force against time history (Figure 3) it is quite clear that the polio patient exhibits nearly platform gait compared with the normal heel-toe gait. The polio gait is characterised by the toe coming in contact with the ground within less than 10% of stance phase after heel strike. Loss of the use of dorsiflexors would partially explain this type of gait. Probable heel cord tightness and lack of dorsiflexion creates a tendency to "platform gait". Correlation of forces in the first 30% of stance phase after heel strike indicates rapid flattening of the entire foot on the surface which is maintained through out the stance phase until heel lift off. Continuous heel support through out the stance phase also indicates plantar flexion weakness. This may have bearing on the design of a suitable orthoses for polio patients, in particular corrective footwear. The individual force patterns can also provide an additional tool to clinicians in the diagnosis of pathological gait.

CONCLUSIONS:

Conclusions drawn from this study are:

1. The transducer can aid in the design of suitable orthoses and corrective footwear for polio patients.
2. The transducer can detect subtler differences between normal and abnormal gait.
3. The transducer can help speed up the training of an amputee in the use of a prosthesis. It is also possible to aid him in the developemnt of a more normal gait (Ranu, 1983a).
4. This method of analysing gait is simple, accurate, non-invasive and has an enormous clinical potential in orthopaedics and the rehabilitaiton of patients with lower extremity disabilities.
5. The contribution of each load cell force-time history in different regions of the foot results in a normal gait-cycle, i.e. a "cummulative gait effect phenomenon" (Ranu, 1983b).

ACKNOWLEDGEMENTS:

I thank Mr. Donald Kerr, Dr. A. I. King, Dr. R. J. Minns and Dr. Harpal Kaur Ranu for their helpful suggestions.

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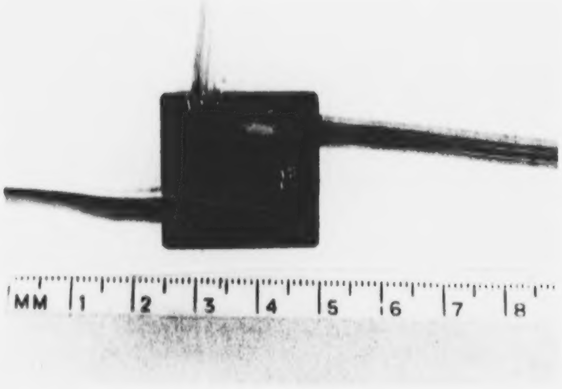

Figure 1. Top View of Miniature Triaxial Shoe Load Cell.

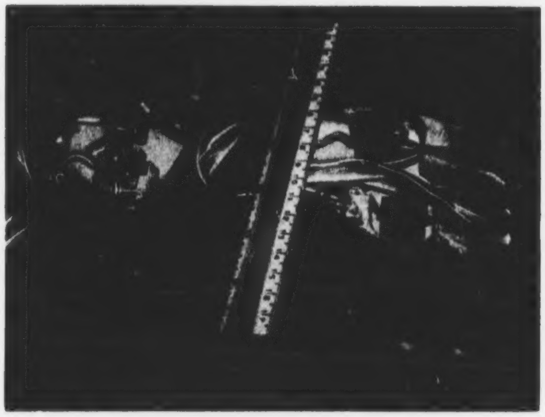

Figure 2. Five Miniature Load Cells Mounted Under a Shoe

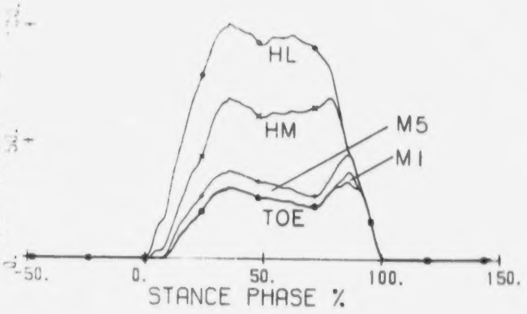

Figure 3. Composite Curve of Vertical Ground Reaction Force for a Polio Victim.

A LASER SCANNING SYSTEM FOR TRACKING LIMB SEGMENT MOTION FOR GAIT EVALUATION

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ABSTRACT - During the course of research on better methods for assessing gait, a system for tracking body limbs segments was developed. Measurements are based on the intersection of three laser planes which define the coordinates of a target photodetector attached to the limb.

RÉSUMÉ - Dans le cours des recherches sur de meilleures méthodes pour l'évaluation de la démarche, un système de poursuite des segments des membres a été mis au point. Les mesures sont basées sur l'intersection de trois plans laser qui définissent les coordonnées d'un photodétecteur cible fixé au membre.

Introduction

There has been a continuing effort to develop improved techniques for assessing gait and providing clinicians with better tools for evaluating therapeutic procedures and assistive devices for the walking disabled.

There have been quite a number of systems developed over the years for tracking body motion during walking. Chen (1) and Taylor (2) provide good descriptions of many presently available systems. A new approach to the measurement problem is suggested, with the goal of achieving reasonable cost without sacrificing resolution, sampling rate, or versatility.

Configuration

The system for tracking limb segments in space is based on a laser scanning capability (3). The configuration involves the intersection of 3 light planes in order to define the coordinates of a point in space as defined by a photodetector.

Spatially separated, low power lasers are used to scan the target field. Coverage of the entire field is accomplished by passing each of three lasers through an optical lens arrangement based on a cylindrical lens plus focusing optics, which produces a plane of laser light in 3-D space. This plane of light is then directed at an eight-sided, mirrored scanner rotating at a constant speed of 3600 revolutions per minute. Each scanner is phased so as to allow only one beam of light in the target field at any instant in time. Since three (x,y,z) locations determine the position and orientation of a rigid body in space, a minimum of three photodetectors on a target board must be attached to each limb segment. It is thus possible to calculate the position and orientation of the attached limb. Given information on the position and orientation of adjacent limbs, one can then calculate the instantaneous center of rotation of the joint and the resulting joint angles.

The measurement area for the gait analysis is a cube 6 feet x 6 feet x 4 feet centered over a walkway incorporating an instrumented force platform (see Figure 1). The subject is asked to walk through the laser scanned volume. The detectors are attached to each limb segment so as to ensure that there is a direct line of sight between the detector and the scanning laser beam.

As the target travels through the scanned volume, the target receivers are triggered by the scanning laser beam. Two fixed reference photodiodes are placed at the perimeter of the field. An electronic pulse is generated each time a photodetector is hit by the moving light. By measuring the elapsed time between pulses from the stationary reference diodes and the moving target, one can derive a measure of the swept angle, given a constant angular velocity for the scanning plane. Using trigonometric relations, the coordinate of the target diode may then be calculated. The hardware is capable of generating 480 (x,y,z) points per second per target diode. By storing and computing every sixth point, it is possible to track the position and orientation of a limb segment at an 80 Hz rate.

Calibration

In order to calculate the coordinates of the target points, the location and orientation of the rotational axes of the laser beams must be determined. This calibration phase is used to further ensure that these axes are parallel and orthogonal in order to reduce the computational burden during actual target tracking.

Triangulation Error Associated With Target Motion

The method of determining the coordinates of the target point has an inherent error due to movement of the target between scans. Consider a two-dimensional example. The target location in 2 dimensions is derived from the angular position of the target when hit by 2 consecutive scans. Scanner 1 hits the target at time t_0 and defines the first base angle α of a triangle. Scanner 2 hits the target at time t_1 and introduces the second base angle β. Given the distance betwen the 2 scanners, one can triangulate to determine the target coordinates. However, the calculated location of the target will be incorrect because target motion has resulted in an erroneous value of β. The error will be largest when either α or β is at its largest. Consequently, the magnitude of the maximum error can be predicted by considering the scanner separation distance, the largest base angle, and an estimate of the maximum velocity of any target.

Clock Frequency Effect

Since all measurements are based on the elapsed time between events, the clock pulse frequency affects the accuracy of the data. If a target trigger should occur between consecutive clock pulses, an error will be generated. Therefore, the angular resolution of the system is limited by the time period of each pulse cycle and, thus, by the frequency of the pulse generator. At present, an 8 MHz pulse generator is being used, giving an angular resolution of 0.92×10^{-4} radians over 30 degrees. The worst case spatial resolution in our prototype configuration would be located at a distal corner and is 0.03 inches. Over a six foot range, this translates to a resolution of 1:2400.

Conclusions

There are a number of systems on the market today for measuring body motion. However, factors such as application, resolution, speed, accuracy, and cost are major considerations in the selection process. Our present configuration has been developed for tracking the 3-D motion of human limb segments during walking in order to achieve appropriate accuracies at reasonable cost.

Acknowledgements

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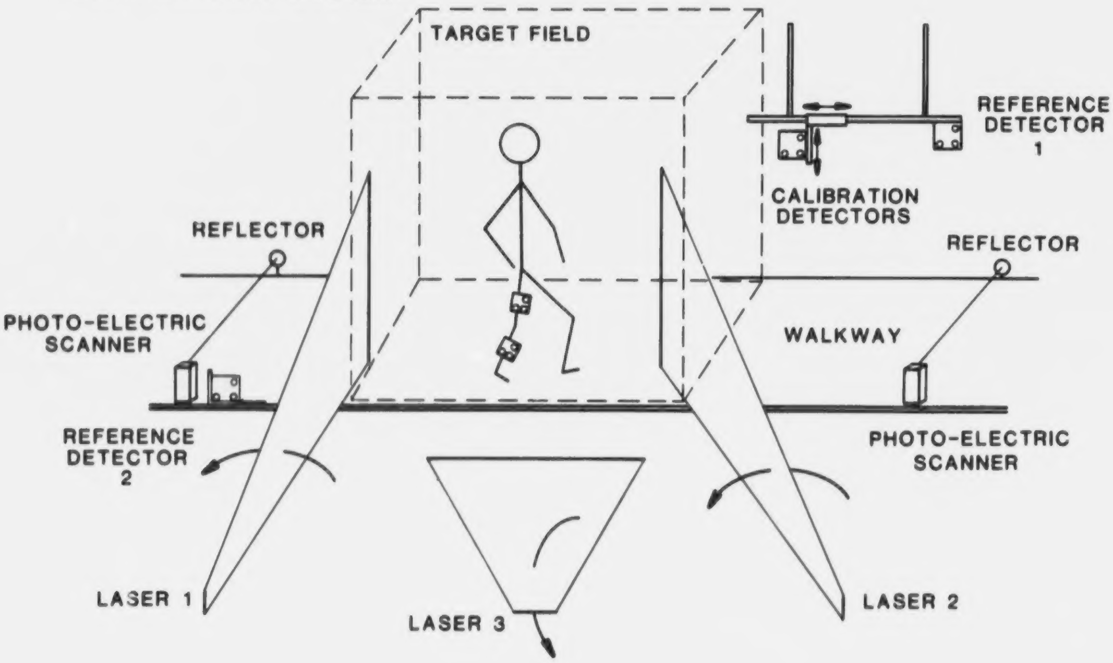
LASER SCANNING SYSTEM-



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